# WASTEWATER TREATMENT SLUDGE AND SEPTAGE MANAGEMENT IN VERMONT

**Vermont Department of Environmental Conservation**
**Waste Management & Prevention Division**
**Residual Waste & Emerging Contaminants Program**

**Ernie Kelley and Eamon Twohig**
**May 2018**

**WASTEWATER TREATMENT SLUDGE**
**AND SEPTAGE MANAGEMENT IN VERMONT**
**May 2018**

# Table of Contents & List of Tables

**WASTEWATER TREATMENT SLUDGE**
**AND SEPTAGE MANAGEMENT IN VERMONT**
**May 2018**

## Introduction

On November 5, 2013, the Residuals Management Section of the Watershed Management Division in the Vermont Department of Environmental Conservation (DEC) [now named the Residual Waste & Emerging Contaminants Program (Program) and located in the Waste Management & Prevention Division] hosted a public forum on the topic of biosolids management. Various stakeholders and citizens, representing a range of viewpoints, attended the forum to make presentations, provide testimony, voice concerns and ask questions. The forum represented DEC's first step toward developing a new set of regulations governing the management of residual wastes. The purpose of this whitepaper is to present a broad overview of the current state of sludge and septage management in Vermont and provide a general survey of scientific research applicable to concerns and issues raised at the forum.

This paper is not intended to establish policy or regulation or to promote one means of residuals management over another. Rather, the intent of this paper is to present a base of information upon which those decisions can ultimately be made. To the greatest extent feasible, the authors of this paper have attempted to present information in a manner that the general public can grasp; and, for those who desire to dig a bit deeper, by providing references to the information cited herein through the use of hyperlinks embedded within the text of the document and in the references section. The studies and references cited represent only a fraction of the research that has been conducted on these issues. As with any subject of scientific research on controversial topics, there is an ample body of literature purporting to support both sides of the issues. This paper attempts to present an unbiased report of both the strengths and weaknesses of that science. To the greatest extent practical, only peer reviewed literature has been cited; although several important non-peer reviewed journal articles and papers are referenced. Where differences in experimental methodology investigating the same question result in significantly different conclusions, we have attempted to provide citations representing both sides. While all methods of using and/or disposing biosolids each comes with its own set of advantages and disadvantages; land application is inarguably the most controversial of the currently employed management practices, hence the major focus of this paper is on the science, regulations, and concerns underlying that practice.

First released in February 2014, this paper has been and will continue to be updated as needed when the Program becomes aware of other relevant research or issues that warrant inclusion.

Ernie Kelley, Program Manager (retired), Residual Waste & Emerging Contaminants Program
Eamon Twohig, Program Manager, Residual Waste & Emerging Contaminants Program

Rev. 5/15/18

## Residual Waste and Biosolids

"Residual waste", as used in Vermont, is a term encompassing several waste materials that are a subset of solid wastes regulated under Vermont law. Primary among these is "sewage sludge" (which will simply be called "sludge" herein) - the solid, semi-solid, or liquid byproduct produced by the treatment of sewage in a wastewater treatment facility (WWTF); and "septage" - the partially treated waste removed from an on-site septic system or a holding tank.

"Biosolids" is defined as sewage sludge which has been subjected to a treatment process for the reduction of pathogens and has been shown to meet the applicable requirements for contaminant concentrations, vector attraction reduction, and pathogen indicator organism density, as necessary for the intended use, such as application to the land under a site-specific permit or marketing and distribution to the general public for unregulated use.

"EQ biosolids", or Exceptional Quality biosolids, is defined as sewage sludge or biosolids that have been subjected to an advanced pathogen reduction treatment process and meet the vector attraction, pollutant concentration, and pathogen indicator organism density standards such that they are no longer classified as a solid waste and may be marketed and distributed to the general public for use without a site-specific permit.

"Secondary residual wastes" include wood ash, short paper fiber, sludge produced by the biological treatment of non-pathogenic dairy wastes, and sludge produced by the treatment of drinking water supplies. The management of secondary residual wastes is beyond the scope of this paper.

The three primary management options for sludge or biosolids that are currently available to Vermont WWTFs are land application after an approved pathogen treatment process, landfilling, or incineration. Although there are several emerging technologies that offer alternative strategies for sludge management (most of which generally fit into those three basic categories), none are currently sited where their use is economically feasible for Vermont municipalities and relatively few are being operated as full-scale facilities with a documentable track record of their capabilities.

Residual wastes can potentially be managed by application to agricultural or silvicultural lands as a valuable nutrient source and soil conditioner. The use of human wastes (night soil) as a fertilizer dates back thousands of years and land application of biosolids resulting from wastewater treatment has been practiced since sewage sludge was first produced (Hartman, 1975). Research into the plant nutrient value of sludge spans several decades (Rudolfs and Gehm 1942, Dowdy et al. 1976, Sommers et al. 1977, Page et al. 1987, Logsdon 1993 (as cited by National Research Council of the American Academies of Science 1996) and Chambers et al. 2007). The noted benefits of biosolids as a soil amendment to agricultural land include a supply of plant essential macro and micronutrients, addition of organic matter to soil, reduced soil erosion, increased water holding capacity, and improvement of soil structure – all of which result in increased soil fertility and crop yields.

Additionally, some benefits of reusing biosolids include conserving space in, and reducing greenhouse gas emissions from landfills. Methane emissions from landfills accounted for approximately 18 percent of the total US anthropogenic methane emissions in 2012, the third largest contribution of any methane source (USEPA 2014). A recent study (Beecher 2008) compared greenhouse gas emissions from different biosolids management options for the Town of Merrimack, NH, concluding that landfilling biosolids would produce roughly 2.5 to 3.4 times more methane than composting. Furthermore, although land applied biosolids will decompose under aerobic conditions and produce carbon dioxide rather than methane (which is about 23 times more potent than carbon dioxide as a greenhouse gas) as the end metabolic product, the substitution of biosolids for fossil-fuel based commercial fertilizers and the carbon sequestration in soils resulting from land application can actually result in a net credit of greenhouse gas (American Society for Microbiology 2011, Canadian Council of Ministers of the Environment 2009). Biosolids are also used in the preparation of manufactured top soils and in land reclamation projects. Brown et al. (2004, 2005) utilized biosolids to reduce the phyto and bioavailability of lead, zinc and cadmium in smelter contaminated soils and alluvial tailings from mining operations. Similarly, Ryan et al. (2004) applied iron-rich biosolids to an urban lot contaminated with lead to successfully reduce lead bioavailability and exposure risk.

Because the land application of biosolids combines cost effective management of these abundant materials with the return of valuable nutrients back to the soil and the enhancement of soil properties and plant yield, the beneficial use of residual wastes has historically been an objective for the management of these materials at both the Federal and State levels. Indeed, the Vermont statutes at 10 V.S.A. 6604 (c) stipulate that a section of the Vermont Solid Waste Management Plan *"shall set forth a comprehensive statewide program for the collection, treatment, beneficial use, and disposal of septage and sludge."*

## Current Biosolids Management: U.S., New England and Vermont

Approximately half of all sludge produced in the United States (~7.1M dry tons per year) is treated to biosolids standards and land applied on less than one percent of the nation's agricultural acreage in crop production (USEPA 2012). In Vermont, as of April 2017, approximately 947 acres of agricultural land is certified and used for the land application of biosolids and septage (approximately 635 and 262 acres, respectively), representing about 0.075% of the state's estimated 1.25 million acres in agriculture and about 0.015% of Vermont's total area (~6.16 million acres) (Figure 1) (USDA 2014). That acreage is comprised of 65 individual sites (43 for biosolids, 22 for septage) ranging in size from 2 – 39 acres, as authorized for 18 permittees (10 municipalities for biosolids, and 8 facilities for septage management). More acreage is authorized for this use than is needed for the annual management of biosolids and septage. In a typical year, about 10% - 15% of the individual fields authorized for septage management are not used at all and those that are used receive, on average, only about 30% - 50% of their approved capacity. Similarly, in a typical year about half of the individual fields authorized for biosolids management are not used at all and those that are typically receive from 50% to 75% of the agronomic loading rate.

The management of biosolids in New England generally follows a trend where southern New England states incinerate most of the sludge produced at their WWTFs while northern New England states rely on a diversity of disposal and beneficial uses (Beecher 2012). For example, in 2011, Connecticut and Rhode Island incinerated the vast majority of the sludge produced in those states while Maine and New Hampshire reused about 74% and 66%, respectively, of those states' biosolids via land application after composting or an equivalent pathogen reduction treatment (Table 1). Individual land application sites are listed in Appendix 10.

**Figure 1. Location of Vermont's Biosolids and Septage Management Facilities.**

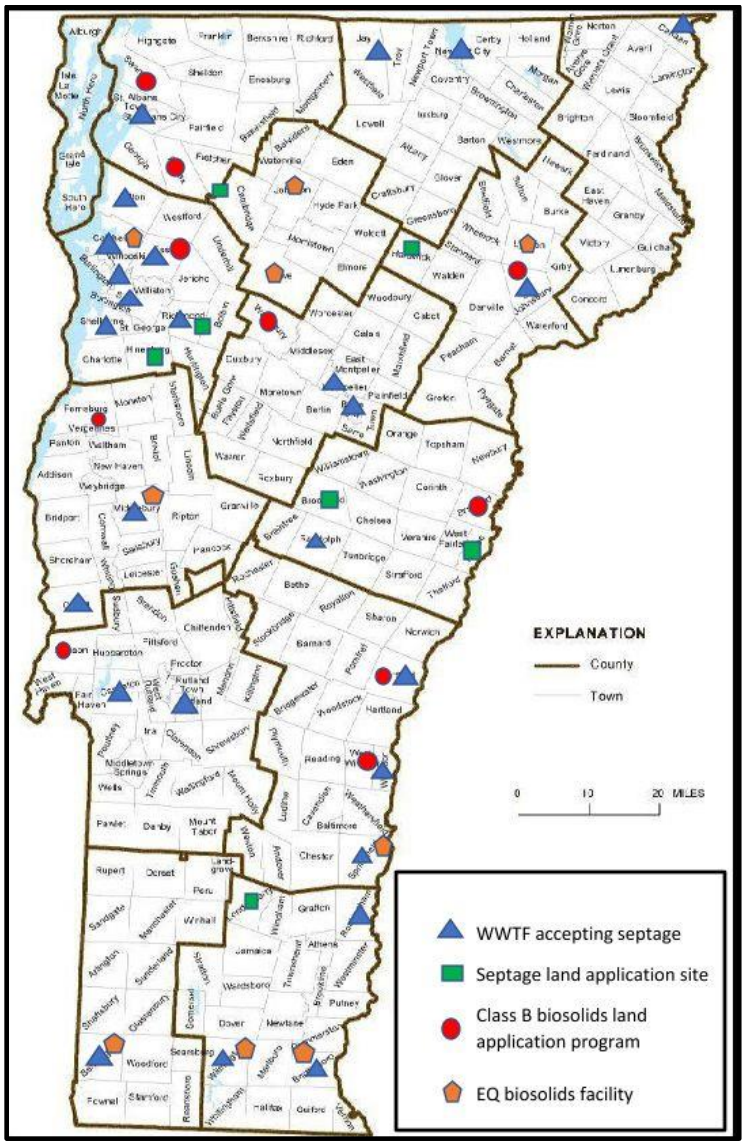


**Table 1. Sludge Disposal Option Percentages (%) and Dry Weights by New England States in 2011.**

| | CT | MA | ME | NH | RI | VT |
|---|---|---|---|---|---|---|
| Incinerate | 99 | 36 | 0 | 16 | 76 | 2 |
| Landfill | 0 | 25 | 26 | 18 | 2 | 69 |
| Reuse (land app and EQ biosolids) | 1 | 49 | 74 | 66 | 22 | 29 |
| Dry Weight (dry US Tons/year) | 11,800 | 20,170 | 29,900 | 28,300 | 27,500 | 12,656 |

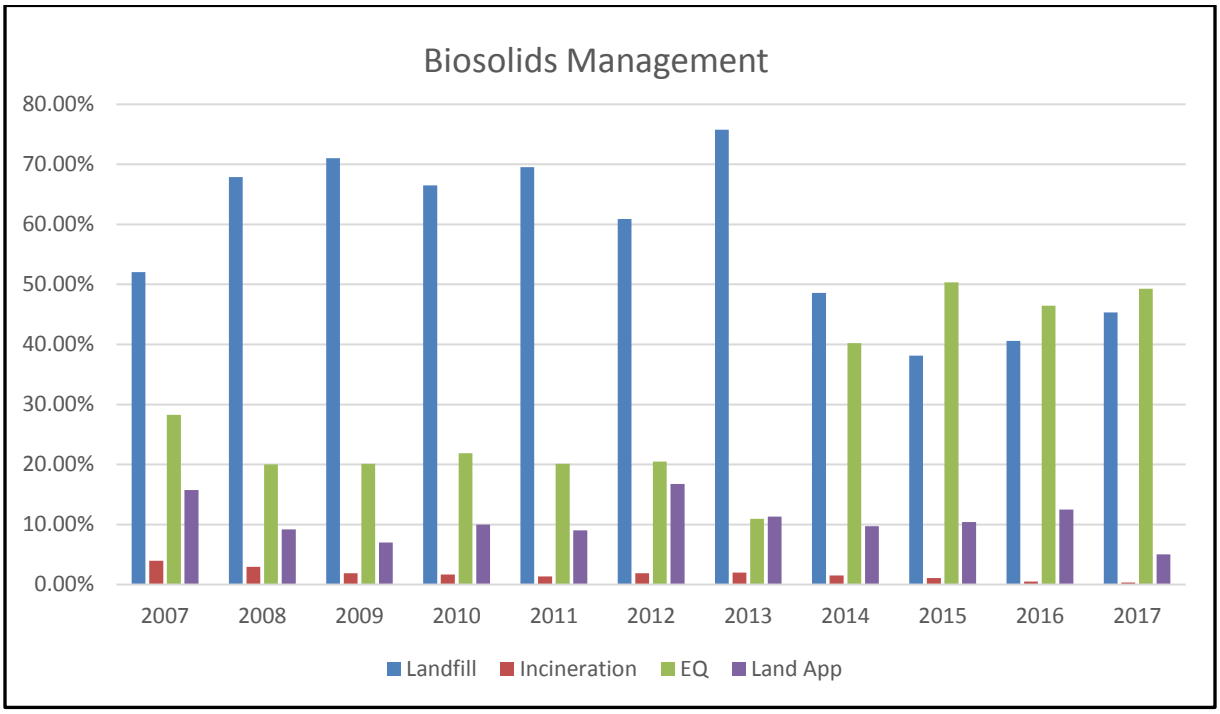
Vermont's biosolids agronomic use rate (both land application and distribution of EQ biosolids) was 73.5% in 1999 but declined over the next fifteen years primarily as the result of a change in management of a majority of the sludge generated by Chittenden County municipal WWTFs that, until 2007, had been composted at facilities in the eastern townships of Quebec. In 2008, Vermont's ninety municipal WWTFs treated more than 17.7 billion gallons of sewage and other wastes which resulted in the generation of approximately 11,225 dry tons of sludge (~74,800 wet tons at 15% solids). Of this total, only 29% was treated to biosolids standards and used in agronomic settings and about 68% was disposed by landfilling - the highest rate in New England. By 2013, only 22% of Vermont's sludge was treated to biosolids standards and used agronomically and 76% was disposed by landfilling. However, in 2014, the Chittenden Solid Waste District (CSWD) contracted with Casella Organics to manage the majority of the District's sludge at Casella's Grasslands Facility in Chateauguay, NY, where biosolids are treated to EQ standards by an advanced lime stabilization process and subsequently used for agricultural purposes. As a result, there was a significant change in the management of the approximately 9,900 dry tons of sludge produced from the treatment of ~15.4 billion gallons of sewage, with only 49% being landfilled and 50% being treated to biosolids standards. The most recent data available (2017) upset the recent general trend that the total volume of sewage being treated is decreasing (most likely a result of stormwater diversion and reductions of collection system inflow and infiltration), the volume of sludge being produced per gallon treated is increasing (most likely a result of enhanced nutrient removal under TMDL requirements), and the rate of beneficial uses of biosolids is increasing (Table 2 and Figure 2). However, 2017 was an unusually wet year (39" rain equivalent versus 28" in 2016). On average over the period 2007 - 2017, approximately 0.69 dry tons of sludge was produced for every million gallons of wastes treated in a WWTF.

**Table 2. Vermont Biosolids Generation and Use Data 2008 - 2017**

| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Landfill** | 67.88% | 71.05% | 66.51% | 69.55% | 60.90% | 75.75% | 48.61% | 38.16% | 40.58% | 45.32% |
| **Incineration** | 2.95% | 1.87% | 1.66% | 1.33% | 1.87% | 1.97% | 1.49% | 1.09% | 0.52% | 0.34% |
| **EQ** | 20.01% | 20.10% | 21.85% | 20.11% | 20.48% | 10.94% | 40.19% | 50.34% | 46.43% | 49.29% |
| **Land App** | 9.16% | 6.99% | 9.98% | 9.01% | 16.75% | 11.33% | 9.71% | 10.41% | 12.47% | 5.05% |
| **TOTAL DRY TONS** | 11,225 | 11,200 | 12,533 | 12,656 | 10,287 | 8,062 | 9,887 | 10,061 | 11,109 | 12,432 |
| **WWTF FLOW (M gal.)** | 17,778.7 | 15,909.6 | 15,802.2 | 19,115.8 | 14,030.3 | 16,270.6 | 15,402.9 | 14,101.9 | 13,191.7 | 15,247.7 |

Note: The WWTF flows in Table 2 do not include CSO volumes, as CSO events do not generate sludge and therefore are not germane to this paper. It should also be noted that the annual biosolids totals also do not include the ongoing production of sludge in lagoon-type WWTFs from which no sludge was removed in any given year.

**Figure 2. Vermont Biosolids Management Data 2007 - 2017**




Although Vermont's universal recycling law, Act 148 (2012), does not include any specific targets for the diversion of residual wastes to beneficial uses and is silent as to its applicability to banning sludge from landfills, any decision affirming its applicability to sludge and septage will be considerable, as a beneficial use rate of 75% remains the standard that the Vermont Agency of Natural Resources (ANR) would like to see accomplished (and would leave land application or incineration as the only remaining options for the disposal of sludge and biosolids).

57.5% of Vermont residences utilize on-site septic systems, the highest percentage in the United States (US Census Bureau 1990). Approximately 37 million gallons of septage was pumped from Vermont's on-site septic systems in 2017 and disposed as shown in Appendix 4: Table A-6 and Figures A-7 and A-8.

Tables A-5 of Appendix 3 and A-6 of Appendix 4 provide breakdowns of sludge/biosolids and septage management in Vermont in 2017. These tables show how those wastes were managed both in-state and out-of-state for the various available management options.

For an overview of biosolids management from a more global perspective, the report prepared by the United Nations Human Settlements Programme and the Greater Moncton Sewerage Commission (New Brunswick, Canada) provides descriptions of how biosolids are managed in thirty-seven other nations and the European Union. A synopsis of pollutant limits for biosolids used in agriculture from a number of those nations is provided in Appendix 8: Table A-11.

## Biosolids Regulation: Federal and Vermont

The Clean Water Act establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was first enacted in 1948 as the Federal Water Pollution Control Act. That Act subsequently underwent a significant reorganization and expansion with amendments in 1972 and became known as the Clean Water Act (CWA).

Under the CWA, EPA implemented pollution control programs such as setting wastewater standards for industry, effluent limits, and water quality standards for contaminants in surface waters. As originally enacted, the CWA did not establish regulations for sludge management.

The CWA made it unlawful to discharge a regulated pollutant from a point source into navigable waters of the United States, unless a permit is obtained from EPA or a state delegated to administer the program for EPA. EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges. The Vermont ANR is delegated to administer the federal NPDES programs for direct discharges, industrial discharges, stormwater, and CAFOs. Point sources are discrete conveyances such as pipes or man-made ditches.

"Navigable waters of the United States" include:

- Traditional navigable waters
- Interstate waters
- Wetlands adjacent to either traditional navigable waters or interstate waters
- Non-navigable tributaries to traditional navigable waters that are relatively permanent, meaning they contain water at least seasonally
- Wetlands that directly abut relatively permanent waters

Individual homes that are connected to a municipal system, use an on-site septic system, or do not have a discharge directly to surface waters do not need a NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. A wide variety of industries also must obtain a NPDES pretreatment permit under 40 CFR Part 403 if they discharge their industrial wastes to a municipal WWTF's collection system rather than directly to surface waters.

Although the Program was not able to locate definitive records, the first WWTF in Vermont likely was constructed in the late 1940s by the City of St. Albans (although the City of Burlington also lays claim to that honor with Burlington's first WWTF completed in 1953 and

equipped with anaerobic sludge digestion). However, it was not until the mid-1960s through the mid-1970s, when significant federal funding for WWTF construction became available, that facility construction throughout the state began in earnest and the discharge of untreated sewage directly into Vermont's waterways really began to come to an end. At that time, sludge management was unregulated under both Vermont's and federal regulations, and it is assumed (although not documented) that most sludge produced in Vermont was either land applied on local farm fields or disposed in the numerous unlined local landfills that existed at the time.

The formal regulation of sludge management in Vermont was first addressed in April 1962 when the Vermont Department of Health (VDH) issued a one paragraph regulation, the text of which could not be located, that was based on public health protection. From that date through the early 1970s, sludge produced by Vermont's WWTFs was managed based solely on its pathogenic nature, primarily via land application. Draft Vermont Guidelines for Sludge Management were first developed by DEC in the early 1970s to supplement the regulation and included basic management practices and the first numerical limits on pollutants.

In 1979, the Code of Federal Regulations (CFR) Title 40, Part 257, the first federal regulations addressing the application of solid wastes to agricultural lands, was promulgated. Part 257 contained numerical limits only for cadmium and polychlorinated biphenyls (PCBs) and established the first pathogen reduction treatment options. The 1981 revisions to the Vermont Guidelines established additional "best practices" and pollutant standards and adopted the pathogen reduction requirements of Part 257.

Before Congress enacted the Ocean Dumping Ban Act of 1988, which prohibited the practice after 1991, wastewater sludge generated in the northeastern United States (except for Vermont and other interior regions) was typically disposed by ocean dumping. For example, starting in the 1920's, sludge generated in New York City was dumped into the relatively shallow waters of New York Harbor only 12 miles offshore until the United States Environmental Protection Agency (EPA) established the Deepwater Municipal Sludge Site, also called the "106-mile Site", on the edge of the continental shelf (average depth of 7,500 feet), where at least 40 million wet tons of sludge was deposited between 1986 and the end of 1991 (Specter 1992). No sludge produced by Vermont WWTFs has ever been disposed in this manner.

In February 1989, the first Vermont Solid Waste Management Rules (VSWMR) were promulgated, establishing most of the recommended practices in the Guidelines as formal regulations. The VSWMR have been revised seven times since they were first promulgated, most recently in March 2012, with most revisions including some enhancements to the sludge/biosolids management regulations.

In February 1993, 40 CFR Part 503, *"Standards for the Use or Disposal of Sewage Sludge"*, was promulgated as a standalone regulation for sludge and septage management and disposal under the federal CWA, some twenty years after the EPA first developed sludge management regulations under Section 405 of the 1972 Water Pollution Control Act (and through amendments to the Act in 1977 and 1987) (USEPA 1993, 1994). Under 40 CFR Part 503,

biosolids use and disposal became a highly-regulated management practice. Part 503 Subparts B and D establish requirements for the disposal of biosolids when they are applied to the land to condition the soil or provide nutrients. Part 503, in Subparts C and E respectively, also establishes specific regulations for surface disposal and incineration – neither of which is a management practice for which facilities are sited in Vermont. "Surface disposal", as defined in Part 503, refers to what is essentially a sludge-only landfill. All sludge disposed in Vermont landfills is disposed in municipal solid waste landfills, which are regulated under 40 CFR Part 258.

In 1998, Vermont submitted an application to EPA seeking federal delegation to administer the sludge management programs in lieu of the federal government. The delegation request was submitted for authority under 40 CFR Part 257 because sludge is defined as a solid waste under Vermont statute, and Vermont was the last state that EPA allowed to do so. In most states, sludge management is regulated under their CWA's NPDES authority, and the eight states currently delegated to administer the biosolids program for EPA are delegated under the CWA's authority of Part 503. However, due to the legalistic conflicts between Parts 503 and 257, Vermont's delegation request has been stalled in EPA's hands since the early-2000s. As of the date of this whitepaper, Vermont is no longer actively pursuing federal delegation for the program, although it has not formally withdrawn its delegation petition.

Beginning in FY2012, EPA began disinvesting in the biosolids management programs regulated under Part 503 under the guise that "the Rule is sufficiently protective of human health and the environment and is self-implementing". The primary areas of disinvestment are in EPA's Office of Enforcement and Compliance Assistance (OECA), the number of FTEs dedicated to the biosolids program at EPA headquarters and in the regional offices, and in providing ongoing technical support and training for the states' regulatory staff. Although EPA's Office of Science and Technology (OST) still performs the biennial reviews of potential biosolids contaminants required under the CWA (the 2013 and 2015 reviews were released by EPA in May 2018) and continues to support the Pathogen Equivalency Committee, EPA otherwise believes that it is capable of ensuring compliance with the regulation through the monitoring, reporting, and recordkeeping requirements of Part 503. However, since 40 CFR 503.18 only requires Class 1 sludge management facilities (defined as those WWTFs with a design flow of greater than one million gallons per day, or which serve a population of 10,000 people or more, or that have an industrial discharge to their collection system from a business that is covered under an NPDES Pretreatment Permit – criteria which captures only 30 of the 90 municipal WWTFs in Vermont) to submit an annual report to EPA of their sludge management activities (with no reporting requirement at all for non-Class 1 sludge management facilities), most Vermont WWTFs receive no federal oversight of their biosolids management activities. And, considering that EPA lacks the staff necessary to conduct timely reviews of the Class 1 facility reports that are submitted (EPA Region 1 currently allots 0.1 FTE to its biosolids program) and the fact that there have been no biosolids program activities or inspections conducted by EPA in Vermont in more than 25 years; in essence, Vermont WWTFs receive no federal oversight of their biosolids programs. However, beginning with the 2016 reporting year (reports to EPA of 2016's activities were due on or before February 19, 2017), EPA implemented its own electronic reporting system for the

annual reports required by 503.18 (but again, reports are required for Class 1 sludge management facilities only), which should somewhat ease the lack of federal oversight and annual report reviews.

In Vermont though, the VSWMR requires that all facilities must submit reports of their biosolids or septage management activities and monitoring data on a quarterly (4 times per year) basis, and all quarterly reports are reviewed by Program staff within thirty to sixty days of their receipt, which affords much more timely compliance oversight than EPA could provide.

So, for all practical purposes, EPA's disinvestment in its biosolids programs will have no impact on Vermont's program since DEC has for more than 25 years been the sole authority administering and enforcing this program in Vermont.

In February 2017, legislation was introduced in the Vermont House of Representatives as House Bill H.211. Section 5 of the bill required ANR to submit a report to the legislature by January 15, 2018, that develops a strategy for banning land application by addressing recommended alternatives to land application, an estimate of the volumes that are currently managed via land application and would need to be alternatively managed, a timeline for implementing the recommended alternative strategies, an estimate of the cost of banning land application, and a summary of the benefits or decreased risks derived from implementation of the alternative strategies. As of this writing, the bill was introduced before the House Committee on Natural Resources, Fish and Wildlife, but no action other than some preliminary testimony was taken in the spring 2017 legislative session, so the report required under Section 5 has not been prepared. The Program opposes the bill in its original form, and has recommended that in order to receive the Program's support, the bill must be revised to mandate a comprehensive review of all biosolids management strategies as they relate to protection of human health and the environment and economics, to submit those findings in lieu of the originally mandated report, and ultimately to use those findings to establish appropriate policy and regulations. The bill was not taken up in the 2018 legislative session, and at this point is considered dead.

In May 2017, the Program initiated the second phase of the rule revision process with the formation of a working group to evaluate how Vermont's residual wastes (specifically sludge and septage) should be managed over the next 15 – 25 years. The purpose of the group (which is composed of WWTF operators; private sector biosolids managers; Lake Champlain International; the Vermont Toxics Action Center; the Green Mountain Water Environment Association; the Vermont Rural Water Association; a hydrogeologist; a soil scientist; the UVM Extension Service; the Vermont Department of Health; the Vermont Agency of Agriculture, Farms, & Markets; and Program staff) is to develop a recommendation on the appropriate methods of managing biosolids and septage. The group's position will be used to formulate ANR policy from which will be developed an entirely new set of regulations for the management of all residual wastes that will replace residual waste regulations currently promulgated under the VSWMR. To assist in that effort, the Program is sponsoring a number of students in an undergraduate class at the UVM Rubenstein School of Environmental & Natural Resources to

conduct a targeted literature search on topics of concern for working group members in the spring 2018 semester.

As of March 2018, the Program is moving forward with revisions to the residual waste regulations in the VSWMRs as part of a major rewrite of the entire rule, rather than proceeding with the envisioned complete separation and rewrite of the regulations for residual wastes (which will take place at a later date). The current revisions are mainly housekeeping matters that include revised definitions, the incorporation of standards established in Part 503 which are not currently in Vermont's regulations, eliminating the TCLP testing requirement, and a ban on winter land application that is the same as the manure spreading prohibition. These include cumulative pollutant loading rates (503.13), pathogen and vector attraction reduction standards (503.32), and monitoring and testing frequencies (503.16). However, the primary change is the establishment of a Certificate of Approval program for EQ biosolids that are not produced in Vermont and which are subsequently imported into the State, which will require any such materials to meet the lower of the Vermont pollutant limits, the Part 503.13 – Table 3 pollutant limits, or the corresponding pollutant limits of the state in which they are generated (even if any given parameter is not otherwise regulated under the VSWMRs or 40 CFR Part 503). Also related to EQ biosolids or biosolids products, the proposed revisions do not recognize Class A - Alternatives 3 or 4 under 503.32 as acceptable Class A demonstrations for EQ materials produced in or imported into Vermont (see further discussion on this matter on page 29), and generally exempts EQ materials that are distributed in Vermont solely in bags or other containers having a net weight of 50 pounds or less from all but the pollutant limits, the limitations on Class A demonstrations accepted in Vermont (as discussed above), and product labelling and recordkeeping requirements.

## Biosolids Risk Analysis and Management Standards

The process of identifying potential pollutants for regulation under Part 503 began in 1984 when EPA developed a list of 200 chemicals for consideration based on available data concerning:

- Human exposure and health effects
- Plant uptake
- Phytotoxicity
- Effects on domestic animals and wildlife
- Effects on aquatic organisms
- Frequency of occurrence in sludge
- The probability that the pollutant would be toxic when exposure occurred through the use or disposal of biosolids
- The availability of toxicity and exposure data

The initial screening eliminated 150 of the originally listed pollutants, due to either their having been banned from production and use in the United States, their low frequency of occurrence/low concentrations in sludge, or because there was insufficient exposure and toxicity

data to make an evaluation; as Congress, in crafting the CWA, specifically established in Section 405 that contaminant standards must be developed:

> *"on the basis of* ***available information*** *on their toxicity, persistence, concentration, mobility, or potential for exposure, may be present in sewage sludge in concentrations which may adversely affect public health or the environment"* (***emphasis*** added)

For each of the remaining 50 pollutants, EPA developed a Hazard Profile that ranked each based on the estimated concentration of the pollutant in soil, plant or animal tissue, groundwater, surface water, or air; and the lowest concentration of the pollutant shown to be toxic via the most sensitive route of exposure. Every pollutant that was scored with a Hazard Profile of greater than 1 (the range was <1 to >1000) was subjected to the detailed risk assessment described briefly below.

To protect public human, animal, soil and crop health from pollutants that are typically present in municipal biosolids, Abt Associates, under contract from EPA, conducted an extensive deterministic risk assessment on the pollutants remaining from the original list, modelling the risk to a hypothetical Highly Exposed Individual using fourteen potential exposure pathways. Ultimately, EPA determined that only 10 of the remaining 50 potential pollutants met the criteria that allowed and required EPA to establish regulatory limits for them, and EPA subsequently set numeric limits for the ten trace elements [Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Selenium (Se) and Zinc (Zn)] with high enough potential risk to warrant regulation (Table 3). The Part 503 technical support documents, in several thousand pages over two volumes, detail the risk assessment's underlying science (TSD - Vol. 1 and TSD - Vol. 2); and the Abt Associates supporting risk analysis EPA has also prepared a document, *"A Guide to the Biosolids Risk Assessment for the EPA Part 503 Rule"* (USEPA 1995).

Ultimately, EPA established the 503.13 - Table 3 EQ biosolids ceiling concentrations at the lower of the risk analysis-based concentration limit or the 99$^{th}$ percentile concentration detected in the NSSS (i.e. – 99% of the samples in the NSSS, and statistically all U.S. biosolids, had concentrations of the pollutant below that number). EPA then back calculated and established the Cumulative Pollutant Loading Rates (CPLR – Table 7 in this document) concentration limits by extrapolating from an assumption that biosolids would be applied to a site at a rate of 10 dry metric tons/hectare-year (8.92 dry US tons/acre-year), each year, for a period of 100 years, where the concentration of each pollutant in the biosolids applied over that period equaled the 503.13 – Table 3 limits. Note that since EPA used 100 years and 10 metric tons/ha-year and a conversion factor of 0.001 to convert from units of mg/kg to kg/ha (100*10*0.001 = 1), the 503.13 – Table 3 numbers and the CPLRs are numerically the same, but differ in units.

**Table 3. Exposure Pathways used in Land Application Risk Assessment.**

| Exposure Pathway | Description of Highly Exposed Individual | Metal limited by pathway |
|---|---|---|
| Biosolids>soil>plant>human | Human (not home gardener) lifetime ingestion of plants grown in amended soil | None |
| Biosolids>soil>plant>human | Human (home gardener) lifetime ingestion of plants grown in amended soil | None |
| Biosolids>human | Child directly ingesting biosolids | **As, Cd, Pb, Hg, Se** |
| Biosolids>soil>plant>animal> human | Human lifetime ingestion of animal products raised on forage grown on biosolids amended soil | None |
| Biosolids>soil>animal>human | Human lifetime ingestion of animal products from animals directly ingesting biosolids | None |
| Biosolids>soil>plant>animal | Animal lifetime ingestion of plants grown on biosolids amended soil | **Mo** |
| Biosolids>soil>animal | Animal lifetime direct ingestion of biosolids | None |
| Biosolids>soil>plant | Plant toxicity from biosolids amended soil | **Cr, Cu, Ni, Zn** |
| Biosolids>soil>soil organism | Soil organism ingestion of soil/biosolids mix | None |
| Biosolids>soil>soil organism>soil organism predator | Predator of soil organisms that have ingested biosolids amended soil | None |
| Biosolids>soil>airborne dust>human | Adult human lifetime inhalation of dust from biosolids amended soil | None |
| Biosolids>soil>surface water>human | Human lifetime drinking surface water and ingestion of fish contaminated with pollutants in biosolids | None |
| Biosolids>air>human | Human lifetime inhalation of pollutants in biosolids that volatilize to air | None |
| Biosolids>soil>groundwater> human | Human lifetime drinking well water containing pollutants leached from biosolids | None |

A more detailed description of each Highly Exposed Individual is presented in Appendix 1.

Since Part 503 was promulgated, EPA has evaluated nearly 1,100 additional chemicals in subsequent biennial reviews using the same criteria and under the same CWA constraints as were used to evaluate the initial group of 200 chemicals in 1984. Of that group, approximately 25 chemicals are now being further evaluated for the need to establish standards, with the remainder having either been eliminated from consideration due to insufficient data or as the result of a risk assessment determining that they presented minimal risk and that a standard was not warranted.

The modelling used by EPA, and the conclusions it used for development of the regulation were independently reviewed by both the Program, VDH, and the National Academy of Science's National Research Council. Those independent reviews concluded that the initial modelling, which employed a deterministic risk analysis approach, was generally sufficient to assure public health and safety and to protect the environment for the ten metals for which standards were ultimately promulgated. EPA switched to using a more modern probabilistic Monte Carlo type approach in subsequent risk analysis models to refine the analysis and verify the results of the initial deterministic modelling. VDH and the Program did express concerns regarding the concentration limits established for arsenic and cadmium (discussed later in this paper), and Vermont's standards were accordingly promulgated at lower concentrations than those in Part 503. Similar concerns were also one of the primary justifications for Vermont adopting a single tier of contaminant standards at levels lower than the absolute ceiling concentrations established in Part 503.13 – Table 1, which neither the Program nor VDH considered to be acceptable.

Perhaps the most misunderstood set of parameters in EPA's exposure pathway modelling centers around how the limits were calculated, the level of risk employed in setting the standards, the population to which those risk levels were applied, and how the risk relates to the general population. Translating risk into everyday language is a difficult undertaking and for the purposes of biosolids, it is further confounded by the necessity to consider both non-cancer risk as well as cancer risk. EPA, in the 'Questions and Answers' section of its document "A Guide to the Biosolids Risk Assessments for the EPA Part 503 Rule" (1994) provided one of the clearer explanations (at pages 109 – 111 of that document) through the series of questions and answers provided below (slightly edited for clarification and updated population estimates).

> Q: What does an incremental cancer risk level of $1 \times 10^{-4}$ mean?
>
> A: For carcinogenic compounds, a $1 \times 10^{-4}$ incremental lifetime cancer risk means there is an increase in the probability of a hypothetical Highly Exposed Individual getting cancer due to exposure to biosolids of 1 in 10,000.
>
> Q: Does this $1 \times 10^{-4}$ risk level mean that as a result of the Part 503 biosolids rule, 32,400 of the 324 million persons living in the United States (1 person for each 10,000 persons) could possibly get cancer because of exposure to biosolids?
>
> A: No, the risk of getting cancer is related only to the population that is exposed to that risk. In the United States, the number of persons highly exposed to biosolids is actually very small. If, for example, 10,000 individuals were in the population of hypothetical Highly Exposed Individuals, then there might potentially be one case of cancer arising in that population from exposure to a particular pollutant in biosolids. If, however, the population of hypothetical Highly Exposed Individuals was 10, then there might potentially be 0.001 case of cancer arising in the population of hypothetical Highly Exposed Individuals from that pollutant.

Q: Were the limits for metals in the Part 503 Rule established based on an incremental lifetime cancer risk of $1 \times 10^{-4}$?

A: No, the Part 503 metals were considered noncarcinogens (they do not cause or induce cancer) for the exposure pathways evaluated.

Q: If the metal limits were not based on an incremental cancer risk of $1 \times 10^{-4}$, then on what basis were they set?

A: The pollutant limits for each of the Part 503 metals in biosolids are based on threshold limits such as a risk reference dose (RfD), which represents the amount of daily intake of a particular non-cancer causing substance that is not expected to cause adverse effects; the RfD is a conservative determination of the upper level of acceptable intake. The RfD (or other threshold limit) was then combined with pollutant intake information (for example, the amount of a pollutant in biosolids taken up by plants that are then ingested by humans or the amount of a particular food consumed) to derive a pollutant limit. Each pollutant limit, all of which are assumed to be highly conservative, are set to protect a hypothetical Highly Exposed Individual (a different human, plant or animal in each of the 14 exposure pathways) from any reasonably anticipated adverse effects of a pollutant.

Ultimately, the risk of adverse health effects due to exposure to biosolids is directly proportional to the level of exposure. If there is no exposure, which is the case for the vast majority of the country's population, then there is no risk to that population of adverse health effects from biosolids. And so, while the cancer risks were modelled at a target risk level of $1 \times 10^{-4}$ and non-cancer risks were modelled based on threshold limits such as RfDs (which are assumed to be conservative), it must be kept in mind that the highest pollutant limits (503.13 - Table 1) were based on the risk to a *hypothetical Highly Exposed Individual* receiving the full exposure used as the model's basis and that actual populations of hypothetical Highly Exposed Individuals in the United States range in size from only a fraction of a person to several persons. In other words, the pollutant limits were set at a level that is protective for the extremely small subset of the U.S. population having the highest level of exposure to biosolids. It therefore follows that the risk of adverse effects to the *general population* derived from biosolids management is exceedingly small and in most cases is approaching (or at) a discernable increased risk of 'none'.

Both VDH and the Program did, however, believe that there were several significant deficiencies in the modelling, mainly in that EPA did not have sufficient data to accurately model the risk derived from numerous organic compounds (including dioxins, for which the needed data was subsequently amassed and modelled by EPA), and radionuclides. Similar concerns were noted by several states and similarly conveyed to EPA. In response EPA conducted several other studies over the period 1982 through 2006 in order to better characterize these other contaminants and to develop standards where appropriate. However, because of Section 405's restrictions, insufficient information has precluded EPA from accurately modelling and thereby

establishing standards on many potential contaminants. Indeed, the standards established for molybdenum in Part 503.13 – Table 3 and chromium in Part 503.13 – Tables 1 and 3 were vacated by federal court actions mainly on the basis that EPA was not able to demonstrate that the information available when the standards were developed was sufficient to satisfy this requirement of Section 405. As of the date of this paper, EPA is continuing to amass the data necessary to establish a new 503 Table 3 molybdenum standard and to consider additional contaminants for regulation under Section 405's constrictions. While the Program recognizes the limitations this places upon EPA and its legal authority to establish standards for other compounds, Vermont simply does not currently have the staffing and expertise that would be necessary to develop appropriate risk-based standards for such contaminants of its own volition.

As a result of EPA's legal preclusion from establishing a more comprehensive set of standards due to inadequate data, policy based decisions in Vermont as well as in other states, have led several to adopt biosolids regulations that are more restrictive than the federal Part 503 rule in order to further safeguard public health and the environment (NEBRA 2007). Tables comparing the Non-EQ and EQ biosolids contaminant limits in each of the fifty states are presented in Appendix 7: Tables A-9 and A-10.

Vermont regulates biosolids and residual wastes under the Vermont Solid Waste Management Rules (the current version became effective 3/15/12) (VSWMR) and has adopted more stringent standards for the diffuse disposal (the term used in the VSWMR for 'land application') of biosolids (Tables 4 - 7). In practice, biosolids management in Vermont is regulated at the most conservative standards established under either the VSWMR or Part 503. For example, Vermont has set pollutant concentrations in biosolids for arsenic, cadmium, and mercury that are lower than all federal levels, has retained its historical standard for polychlorinated biphenyls (PCBs), and has maintained the 503.13 - Table 3 standards for molybdenum and chromium despite their having being dropped from Table 3 of 40 CFR 503.13 due to federal court action (Molybdenum notice and Chromium Decision).

Under 40 CFR 503.13, two tiers of contaminant concentration limits are established: 503.13 - Table 1 (the higher ceiling concentrations for biosolids that can only be applied to permitted, controlled sites); and 503.13 - Table 3 (the lower maximum concentration of contaminants in biosolids that can be marketed and distributed to the general population as an unregulated commodity). Vermont has adopted one tier of contaminant standards (§6-702 VSWMR) for all biosolids that are to be applied to the land or marketed and distributed to the general public that are more stringent than or equal to the more conservative federal standards in 503.13 – Table 3.

**Table 4. Comparison of Federal and Vermont Pollutant Concentration (mg/kg, dry wt.) Standards for Land Applied Biosolids.**

| | As | Cd | Cr | Cu | Pb | Hg | Mo | Ni | Se | Zn | PCB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 503.13 – Table 1 | 75 | 85 | N/R | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | * |
| 503.13 – Table 3 | 41 | 39 | N/R | 1500 | 300 | 17 | N/R | 420 | 100 | 2800 | * |
| Vermont | 15 | 21 | 1200 | 1500 | 300 | 10 | 75 | 420 | 100 | 2800 | 10 |

N/R = regulatory standard vacated by federal court action.
* = No standard established in Part 503, but *any* waste containing >50 mg/kg PCB *must* be managed per 40 CFR Part 761 and not per Part 503 or other regulations relating to waste management.

As previously stated, Vermont DEC has opted to take the more conservative approach and to retain the federal standards for chromium and molybdenum despite the federal court action that vacated those standards in Part 503.

Industry lawsuits were successful in convincing the federal court that the chromium standard was not risk based (as required by the CWA) in that no evidence was presented that chromium in sludge exists in the toxic and carcinogenic hexavalent ($Cr^{+6}$) form (in sludge, only the non-toxic trivalent [$Cr^{+3}$] or elemental forms would be expected) and because EPA established the chromium standard at the NSSS's 99$^{th}$ percentile value (i.e. – 99% of the chromium concentrations found in the NSSS were below that concentration) instead of the higher risk based concentration. For molybdenum, the court found that the risk to grazing animals from molybdenum (via the disease molybdenosis, caused by a dietary molybdenum/copper imbalance) was inconsequential when the copper concentration met the higher 503.13 - Table 1 standard, and vacated only the 503.13 - Table 3 molybdenum standard on those grounds.

Before Part 503 was promulgated, Vermont had already adopted a lower cadmium standard of 25 mg/kg (dry wt.) in the VSWMR. The cadmium limit was then lowered to 21 mg/kg (dry wt.) in a subsequent rule revision due to concerns raised by Dr. Rufus Chaney and the United States Department of Agriculture (USDA) regarding potential export restrictions on grains and sunflower kernel to the European Union, which has adopted extremely low limits for cadmium in those commodities. The lower Vermont standard of 15 mg/kg (dry wt.) for arsenic was adopted after Part 503's promulgation due to the VDH's concerns regarding perceived deficiencies in how the Part 503 risk assessment dealt with the carcinogenic potential of inorganic arsenic compounds (Southworth 1995).

Because there is scant research into which form of arsenic compounds exist in sludge (non-carcinogenic organic vs. carcinogenic inorganic compounds), VDH opted to again take a conservative approach and assume that all arsenic in sludge exists as carcinogenic inorganic compounds and determined that it was appropriate to establish a standard on that basis.

Although VDH's analysis concluded that a cancer risk based arsenic standard of 10 mg/kg (dry wt.) was appropriate; the complex, organic rich matrix of biosolids produces analytical interferences such that laboratories (at the time that the standard was adopted) were unable to

reliably attain detection limits at that concentration. As a result, the arsenic standard was established at 15 mg/kg (dry wt.) in the VSWMR, the lowest limit that laboratories could reliably achieve in order for permittees to be able to definitively demonstrate compliance. The historic standard of 10 mg/kg (dry wt.) for mercury established in early versions of the VSWMR was retained in the current Rule. Similarly, the historic standard of 10 mg/kg (dry wt.) for PCB as established in 40 CFR 257.3-5 and in early versions of the VSWMR was retained. Part 503 has never contained a standard for PCBs, although biosolids (or any wastes) containing PCBs in concentrations of 50 mg/kg (dry wt.) or greater must be disposed in accordance with 40 CFR Part 761.

Table 5 presents information on metal and nutrient concentrations detected in biosolids produced by all Vermont WWTFs (not just those applied to the land or treated to EQ standards) during the period January 1, 2000 – April 2018, as determined from a database of 41,320 analytical results for the listed parameters. The statistics were calculated using the full minimum quantification limit (MQL) for all results that were reported as "less than" (approximately 21% of all results), rather than using one-half of the MQL as is frequently done in such calculations. The impact of calculating statistics in this manner can be shown with the data for selenium, where the arithmetic mean/geometric means at the full MQL are 6.04/4.81 mg/kg, respectively, and where the arithmetic mean/geometric means at one half of the MQL are 3.89/2.92 mg/kg, respectively. Using the full MQL values therefore provides the "worst case" values with which to work. Approximately 0.5% of results exceeded land application standards (although none of those materials were applied to the land). For comparison with the 2000 - 2018 averages provided in Table 5, the 2017 average concentrations of the nine regulated parameters are provided in Table 6 (full 2018 data is not yet available).

**Table 5. Metal (mg/kg, dry wt.) and Nutrient (%, dry wt.) Concentrations in Vermont Biosolids 2000 - 2018.**

| Parameter | Arithmetic Mean | Geometric Mean | Median | Maximum | Minimum | # of results < MQL* | Sample Size (N) |
|---|---|---|---|---|---|---|---|
| Aluminum | 28,591.68 | 18,302 | 24,500 | 283,000 | 21.40 | 1 | 1,007 |
| Antimony | 3.33 | 1.95 | 1.40 | 13 | 0.80 | 2 | 7 |
| Arsenic | 6.78 | 4.70 | 5 | 169 | 0.01 | 1,256 | 2,504 |
| Barium | 350.05 | 264.99 | 300 | 5,688 | 0.09 | 7 | 1,155 |
| Beryllium | 1.06 | 0.41 | 0.32 | 6.98 | 0.05 | 59 | 71 |
| Boron | 47.14 | 21.52 | 21 | 3,400 | 0.30 | 280 | 804 |
| Cadmium | 2.55 | 1.61 | 1.70 | 120 | 0.01 | 1,128 | 2,561 |
| Calcium | 23,820.32 | 20,782.98 | 21,000 | 98,800 | 1,170 | 1 | 311 |
| Chromium | 27.66 | 20.71 | 22.10 | 270 | 0.03 | 35 | 2,597 |
| Cobalt | 5.72 | 4.15 | 3.95 | 67 | 0.16 | 336 | 641 |
| Copper | 465.98 | 371.26 | 420 | 3,960 | 2.80 | 0 | 2,618 |
| Iron | 18,900.73 | 14,127.29 | 13,000 | 189,100 | 28 | 1 | 788 |
| Lead | 41.94 | 28.94 | 32 | 475 | 0.41 | 232 | 2,580 |
| Magnesium | 4,483.91 | 3,759.81 | 3,485 | 56,000 | 0.33 | 0 | 344 |
| Manganese | 312.10 | 130.82 | 270 | 742 | 0.67 | 0 | 7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Mercury | 1.17 | 0.67 | 0.71 | 70 | 0.0047 | 855 | 2,572 |
| Molybdenum | 13.35 | 8.48 | 8.80 | 660 | 0.08 | 846 | 2,547 |
| Nickel | 24.01 | 15.29 | 15 | 980 | 0.05 | 126 | 2,692 |
| Selenium | 6.04 | 4.81 | 4.86 | 69 | 0.01 | 1,790 | 2,484 |
| Silver | 21.68 | 11.81 | 11 | 220 | 0.01 | 408 | 1,168 |
| Sodium | 963.92 | 780.02 | 850 | 4,000 | 7.88 | 1 | 39 |
| Thallium | 1.97 | 1.56 | 1 | 4 | 0.80 | 3 | 7 |
| Zinc | 765.88 | 553.63 | 680 | 5,606 | 0.50 | 4 | 2,594 |
| Ammonia - N | 0.99 | 0.43 | 0.62 | 9 | 0.000017 | 17 | 1,573 |
| Nitrate - N | 0.11 | 0.0044 | 0.0020 | 6 | 0.0000010 | 712 | 1,701 |
| Nitrite - N | 0.0079 | 0.0008 | 0.0008 | 2.86 | 0.00001790 | 476 | 644 |
| TKN | 4.52 | 3.39 | 4.50 | 26 | 0.00006 | 4 | 1,707 |
| Total Phosphorus | 2.26 | 1.61 | 2.13 | 9 | 0.00018 | 1 | 1,727 |
| Total Potassium | 0.35 | 0.25 | 0.25 | 9 | 0.00002 | 6 | 1,870 |

***** below Minimum Quantification Limit (2018 data through 3/31/18)

**Table 6. Average Metal Concentrations (mg/kg, dry wt.) in Vermont Biosolids in 2017.**

| Parameter | Arithmetic Mean | Geometric Mean |
|---|---|---|
| Arsenic | 5.21 | 4.19 |
| Cadmium | 1.10 | 0.89 |
| Chromium | 32.52 | 22.05 |
| Copper | 384.79 | 285.55 |
| Lead | 41.81 | 29.49 |
| Mercury | 0.67 | 0.37 |
| Molybdenum | 9.34 | 6.95 |
| Nickel | 25.44 | 14.15 |
| Selenium | 7.54 | 6.29 |
| Zinc | 769.90 | 511.88 |

The charts provided in Appendix 9 show significant reductions in the concentrations of the most toxic regulated metals during the period of 2000 – 2017 due to the ongoing implementation of pretreatment programs and pollution prevention efforts, and present-day concentrations for most metals, as shown in Table 6, are well below the averages presented in Table 5.

The Program also conducted a study in 1997 that sampled sludge from 83 Vermont municipal WWTFs and analyzed the samples for metals, nutrients, volatile and semi volatile organics, PCBs, and pesticides/herbicides. The results of that study are presented in Appendix 9. Although this is "old data", it nonetheless documents concentrations of a wide variety of pollutants commonly found in biosolids (although not what are today considered to be "chemicals of emerging concern") and further supports that there has been a marked decline in the concentration of many pollutants over the following years.

In 1999, the Program conducted a project that sampled sludge, composted biosolids, and heat dried biosolids from 19 Vermont facilities, with duplicate samples taken from four of those WWTFs, and analyzed the samples for all polychlorinated dibenzodioxin (PCDD) and dibenzofuran (PCDF) congeners with chlorine atoms in the 2,3,7, and 8 positions (17 different congeners). Results ranged from 1.32 to 59.44 ppt TEQ with an average of 11.22 ppt TEQ when calculated using the 1989 EPA developed NATO I-TEFs. When calculated using the newer and now accepted 2005 World Health Organization TEFs (see Appendix 6), the TEQs decreased to a range of 0.46 – 35.96 ppt TEQ with an average of 8.58 ppt TEQ. The differences are *entirely* due to the reduction of the TEFs for the predominant congeners detected, the octa-chlorinated PCDD/PCDF congeners (the least toxic congeners) from 0.001 to 0.0003, as there were no changes to the TEFs for any other detected congeners. The octa-chlorinated congeners are almost exclusively produced by low temperature combustion of numerous materials ranging from natural wood to plastics and other garbage. These values are still significantly lower than what EPA proposed, but ultimately did not adopt, as a dioxin standard for land applied biosolids – 300 ppt TEQ. No tetra- or penta-chlorinated PCDD or PCDF congeners, the most toxic, were detected in any of the samples; and hexa-chlorinated congeners were only found in two samples.

However, the primary current concern regarding the currently regulated pollutants lies with the toxic heavy metal arsenic, the major exception to the decreasing trend of most metals; which since 2008 has reversed its declining trend of 2000 - 2008. The elevation in mean arsenic concentrations is due almost exclusively to the installation and operation of several arsenic removal systems on municipal drinking water supplies. Unfortunately, in almost all cases, the residue generated from backwashing the arsenic filters is being disposed in the municipality's WWTF rather than being managed in an alternate, albeit more expensive manner. A primary example of the effect arsenic removal sludge can have on biosolids quality is the City of Newport, where the disposal of the arsenic removal sludge (which passes the TCLP extraction test and therefore is not classified as a hazardous waste, despite it being an arsenic compound) in the City's WWTF has resulted in that sludge having among the highest arsenic concentrations in the nation (as high as 169 mg/kg, dry wt.) which necessitated the City to abandon its long standing and very successful land application program and resort to landfilling the sludge for disposal. Additionally, as with any pollutant introduced into a WWTF, arsenic will partition between biosolids and effluent, with conventional activated sludge processes (as used in Newport) having among the lowest arsenic removal efficiencies (~38%; Yang et al. 2015). Because the large majority of soluble arsenic will partition to the effluent stream, this disposal method has the potential to result in the discharge of significant quantities of arsenic into the receiving water, Lake Memphremagog. The Program is diametrically opposed to the use of WWTFs as an 'easy' or 'cheap' solution to the management of wastes that can be otherwise properly disposed, especially those with the toxicity of arsenic, but has no authority to prohibit the practice.

Regardless of the trends of the currently regulated pollutants, these data should not be construed to mean that there are similar trends with contaminants of emerging concern and other unregulated pollutants, and the arsenic chart demonstrates how much of an impact that one or

two facilities with abnormally elevated concentrations of a pollutant can have on the overall statistics.

Part 503.13 - Table 4 establishes Annual Pollutant Loading Rates (APLR) for any biosolids that are applied to the land under the 503.13 – Table 1 ceiling concentrations. The APLRs limit the mass of the regulated pollutants that may be applied to a site in any running 365-day period. Since Vermont has not adopted the Part 503 two tiered Table1/Table 3 approach to contaminant standards, and because it is virtually impossible to load a site to the APLR limits under the 503.13 – Table 3 or Vermont pollutant limits when agronomic application rates are observed, Vermont does not regulate based on the federal APLR limits. The only exception to this is that the VSWMR has always had an established APLR for cadmium of 0.45 lbs Cd/ac-year (again, derived from 40 CFR Part 257.3-5). Any other APLRs based on concerns held by the Vermont Agency of Agriculture, Food, & Markets (VAAFM) should be considered.

40 CFR 503.13 - Table 2 establishes Cumulative Pollutant Loading Rates (CPLR), the maximum mass of a pollutant that may be applied per acre (or hectare), for biosolids that are applied to the land (Table 7). With the exceptions of cadmium, where the VSWMRs has retained its historic standard (again, derived from 40 CFR Part 257-3.5) of 4.5 lbs Cd/acre (5.0 kg Cd/hectare) compared to the federal standard of 39 kg Cd/hectare (34.7 lbs Cd/acre); chromium and molybdenum, where Vermont continues to enforce the CPLRs for these contaminants that were vacated by the federal court action; and arsenic, where the federal CPLR was decreased in proportion to the reduced ceiling concentration (from 75 kg As/hectare down to 15 kg As/hectare); Vermont observes the federal standards despite having not yet been formally adopted in the VSWMR.

**Table 7. Federal and Vermont Cumulative Pollutant Loading Rate Limits (kg/ha).** *

| | As | Cd | Cr | Cu | Pb | Hg | Mo | Ni | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| Vermont | 15 | 5 | 1200 | 1500 | 300 | 17 | 75 | 420 | 100 | 2800 |
| 503.13 | 41 | 39 | N/R | 1500 | 300 | 17 | N/R | 420 | 100 | 2800 |

*Note: kg/ha x 0.89 = lbs/acre; 1 hectare (ha) = 2.47 acres
N/R = no regulatory standard established.

Given that in Vermont, 8.92 dry tons/acre-year (the application rate upon which the 503.13 – Table 3 limits are based) is approximately double the normal agricultural application rate in Vermont and that the longest known use of any single land application site is slightly over 25 years, the standards established in Vermont provide an additional margin of safety for biosolids use. As an example, for a new land application site that has 5 dry US tons per acre of biosolids applied every consecutive year, where all pollutants in the biosolids are at their maximum allowed concentration under Part 503 – Table 1 and the site is loaded to the maximum allowed under 503.13 – Table 2, the site life will be limited by mercury with a useful life of 26 years. When calculated using the Vermont ceiling concentrations and the 2016 Vermont average concentrations with the Vermont maximum loadings (again, at 5 dry tons/acre), cadmium and

arsenic are the limiting pollutants with usable site lives of 21 and 167 years respectively. At the other extreme, it would take 4,144 years to reach the cumulative loading limit for chromium under the 2016 average concentration/Vermont maximum loading scenario at a 5 dry tons/acre application rate.

Application rates for biosolids and septage are strictly controlled. The Program has developed an Excel® based spreadsheet model (Application Rate Model) for calculating application rates based on both nitrogen and phosphorus. The model is based on research conducted at the University of Vermont (UVM) on nitrogen mineralization rates under Vermont's climate conditions and on the UVM Agricultural Extension Service's "Nutrient Recommendations for Field Crops in Vermont" (December 2017 revision). Historically, application rates have been calculated based solely on the nitrogen content of the biosolids with respect to the annual nitrogen requirement of the crop being grown on the site, with the ultimate goal being a net balance of 'zero' between the mass of nitrogen applied and the amount removed by crop uptake. Additionally, although not required under the VSWMR, the Program requires that the application of biosolids to all permitted sites must be done under an approved Nutrient Management Plan. This is generally accomplished by including biosolids management as a part of the farm's approved National Resource Conservation Service (NRCS) Nutrient Management Plan (NMP). NMPs are now required under Vermont's new (December 2016) Required Agricultural Practices regulation.

Due to developing concerns regarding the potential for phosphorus transport from agricultural lands to surface waters, especially in the Lake Champlain basin with the establishment of a total maximum daily load (TMDL) for phosphorus and with excessive phosphorus levels in agricultural soils, the Program has expanded the model to include phosphorus as a potentially limiting nutrient. Staff at the VAAFM's Agricultural & Environmental Testing Lab recently made changes to the Vermont Phosphorus Index for biosolids (the incorporation of a source coefficient to account for the difference in phosphorus solubility between manure and biosolids and based on whether the WWTF employs biological phosphorus removal versus a chemical precipitation process), a task that had to be accomplished in order to obtain accurate application rates from the phosphorus side of the application rate model. The Program is striving to achieve the goal that by the end of 2018, application rates will be based on the more restrictive of these two nutrients. Although the water extractable phosphorus (WEP) content of biosolids, a key indicator of their potential to release phosphorus to runoff, is far lower than manure (3% in digested biosolids vs. 48% in dairy manure) (Moss et al. 2002), the implementation of application rates based on biosolids' phosphorus content could potentially present additional challenges to existing land application programs. Typically, in cases where phosphorus is the limiting nutrient, it is not due to crop nutrient requirements, but rather to either a pre-existing overabundance of phosphorus in a site's soils or because the site features highly erodible soils proximate to surface water. Biological phosphorus removal results in higher concentrations of phosphorus in biosolids, and a large majority of the phosphorus exist in a form that is relatively soluble in water and immediately plant available. This results in a significantly reduced application rate and a correspondingly greater acreage need per unit volume of biosolids.

Removal of phosphorus by chemical precipitation results in a sludge that is predominantly insoluble in water and, while increasing the overall amount of sludge produced by a WWTF, will not have the same impact on land application programs because the two sludge streams typically are not intermingled, and the Program has generally not allowed the management of sludges produced by the chemical precipitation of phosphorus because they usually have minimal nutrient value. These sludges are typically disposed in a landfill, so a substantial increase in the volume so disposed is expected. The Program and several NRCS sponsored studies are however, exploring the potential use of these precipitate sludges as a method of immobilizing soluble phosphorus in soils where the phosphorus concentration is excessive. Any such use would only be approved following close consultation with VAAFM and their approval of using the precipitate sludge for that purpose.

Vermont's land application site monitoring requirements also go beyond the federal requirements established in 40 CFR 503.16, including annual or bi-annual soil and groundwater testing, as well as plant (forage) analysis once each certification period (Tables 8 and 9). Under 503.16, the large majority of Vermont's WWTFs would only be required to monitor the quality of their biosolids once per year, based on their low biosolids production rates. However, it is important to note that Part 503 does not establish any monitoring frequencies for biosolids that are not applied to the land or treated to EQ standards. Vermont is one of the few states that requires groundwater monitoring at land application sites and is the only state that requires periodic testing of the plant tissue of crops raised on land application sites.

**Table 8. Comparison of Vermont and Federal Monitoring Requirements for Biosolids and Land Application Sites.**

| Media | Vermont | 40 CFR 503.16 |
|---|---|---|
| Biosolids | Every batch applied to the land or distributed to the public<br>-or-<br>minimally, per the table below | Varies based on mass produced, per the table below |
| Groundwater | Minimum: once per year | None |
| Soil | Minimum: once per year | None |
| Plant Tissue | Once per permit cycle | None |

**Table 9. Biosolids Production (dry metric tons, in any 365-day period) and Corresponding Federal Monitoring Frequency for Land Applied Biosolids.**

| Volume | 40 CFR 503.16 |
|---|---|
| >0 to <290 | Once per year |
| 290 to <1,500 | Once per quarter |
| 1,500 to <15,000 | Every 60 days |
| >/= 15,000 | Monthly |

*Biosolids in lagoon WWTFs are typically tested only when a lagoon clean-out is conducted.

The Burlington Main WWTF produced the most sludge in the state in 2017 (~415 dry metric tons), for which 503.16 would require quarterly monitoring if the sludge was managed via land application. However, the vast majority of Vermont's WWTFs (85 of 94) fall into the lowest production category and under 503.16 would only be required to monitor on an annual basis, regardless of the management strategy they used or the frequency at which management or disposal events are conducted. For Vermont's lagoon type systems (25 WWTFs), testing is only required when solids are removed from the lagoon (typically every 5 – 10 years). It should be noted that Part 503 does not impose any monitoring or quality requirements for biosolids that are disposed in a municipal waste landfill.

Part 503, in Subchapters C and E, also establishes minimal pollutant limits for incinerated sludge and sludge disposed in a surface disposal (an unlined sludge only landfill) facility. For surface disposal, Part 503 establishes limits based on the distance from the impoundment area to the facility property line for only arsenic, chromium, and nickel. For incineration, Part 503 only establishes pollutant limits for arsenic, cadmium, chromium, lead, and nickel. No surface impoundment or incineration facilities are located in Vermont.

In Vermont, operators of land application sites are also required to install a network of groundwater monitoring wells, minimally comprising of one up gradient and two down gradient wells, to enable a comparison of the quality of ground water entering and then exiting a site after flowing under the active application area. Groundwater monitoring is not required under Part 503. The Program has amassed over 25 years of monitoring data documenting the effects (or lack thereof) of land application on groundwater beneath such sites. In addition, minimum isolation distances established under the VSWMR at §6-503 are either more restrictive than the corresponding federal standard (503.14) or are established where no federal standards exist (Table 10).

**Table 10. Comparison of Vermont and Federal Minimum Required Isolation Distance (in feet) Requirements.**

| Distance to | Vermont | 40 CFR 503 |
|---|---|---|
| Saturated soil at time of application | 3' | None |
| Bedrock | 3' | None |
| Surface water | 100' | 10 meters (33') |
| Property line | 50' | None |
| Residences, schools, etc. | 100' | None |
| Drinking water sources * | 300' | None |

* may be reduced if the facility is hydrologically down gradient of the source

The VSWMR, in Subchapter 5, also establishes that sludge or biosolids management facilities may not be sited in the following designated areas:

- in Class I and Class II Groundwater areas
- in Class I and Class II wetlands and associated buffers, absent a Conditional Use Determination
- in Class III wetlands, absent a Part 401 Water Quality Certification
- in a National Wildlife Refuge
- in a Wildlife Management Area administered by the Vermont Department of Fish & Wildlife
- in a designated threatened or endangered species habitat
- in the watershed for a Class A Water
- within 500' of an Outstanding Natural Resource Water
- within Zone 1 or Zone 2 of a Public Water Supply Source Protection Area; except that on a case-by-case basis, facilities may be sited in Zone 2 of Public Water Supply Source Protection Area for surface water sources only.
- within the floodway portion of a 100-year floodplain.

Part 503 does not establish any areas in which the land application of biosolids or septage is completely prohibited other than in areas where it *"is likely to adversely impact a threatened or endangered species…or it its designated critical habitat"* [503.14(a)].

The EPA also developed standards for pathogen reduction and vector attraction reduction (VAR), codified at 503.32 and 503.33, respectively, and determined appropriate treatment technologies capable of achieving these reductions prior to land applying biosolids.

The VAR standards were established by EPA as a means of setting criteria intended to demonstrate the degree by which the putresibility of the biosolids is reduced in the treatment process as a means of controlling the generation of nuisance odors, which are the main attractants for flies and other vermin that could potentially spread pathogens. Generally, the VAR options all measure the reduction in the amount of putrescible volatile solids in biosolids. While Vermont accepts any of the twelve VAR demonstrations established under the federal regulation, the same is not the case for the pathogen reduction demonstrations established in Part 503.33. Under Part 503, two tiers of pathogen reduction standards are established – Class A and Class B, which are not universally accepted in Vermont.

Pathogen reduction is not measured by culturing and enumerating specific human pathogens, mainly due to the hazards of doing so and the scarcity of laboratories holding the federal permits and level of security necessary to culture such pathogens. Instead, indicator organisms – *fecal coliforms* and *salmonella s.p.*, bacteria that are ubiquitous in the environment, are used as surrogate indicators. *Salmonella s.p.* was selected because they are typically present in higher densities in sewage than other bacterial pathogens and are at least as resistant to treatment as other specific pathogens. *Fecal coliforms* are enteric bacteria that were selected because they are also present in high densities in raw sewage and, although not normally human pathogens, *fecal*

*coliforms* are excellent indicators of the survivability of other truly pathogenic species in treatment processes.

Class B biosolids are comprised of sludge which has been subjected to a Process to Significantly Reduce Pathogens (PSRP), or an equivalent process approved by EPA's Pathogen Equivalency Committee (PEC) or the permitting authority (ANR, in the case of Vermont). However, in general, the Program is extremely hesitant to approve the use of any alternative process (for Class B or Class A treatment) which has not been vetted and received an equivalency determination from the PEC. PSRP processes are typically low temperature aerobic or anaerobic digestion regimes or low temperature stabilization with hydrated lime, which result in the reduction, but not the elimination, of pathogen indicator organisms in the biosolids. The targeted level of treatment for a PSRP results in a minimum of a two log (99%) reduction in the density of indicator organisms, *fecal coliforms* or *salmonella s.p.*. Because PSRP methods reduce, but do not eliminate, pathogens in biosolids; in Vermont, Class B biosolids may only be applied to sites which are specifically authorized for such use under a Solid Waste Management Facility Certification issued by ANR. Sites used for the management of Class B biosolids are also subject to a wide range of site use restrictions designed to further reduce the potential for public health and environmental hazards that could derive from contact with the Class B biosolids. Permittees operating sites to which Class B biosolids or stabilized septage is applied are required to implement the following site use restrictions:

- application of biosolids to frozen or snow-covered ground is prohibited
- application of biosolids where there is less than 36 inches of unsaturated soil is prohibited
- public access to the site must be restricted for a period of twelve months following the last application event (Note: the Rule requires "restricted" access, not "prohibited" access)
- the pH of the site's soil must be maintained in the range of 6.5 – 8.0 S.U.
- domestic food source animals may not be grazed on a biosolids amended site for a minimum of six months following the last application event
- sites may not be used for the production of crops for direct human consumption for a minimum of 36 months following the last application event (38 months if the harvested part grows below the ground surface, per Part 503)
- feed crops may not be harvested for a minimum of five weeks following the last application event
- silage grown on biosolids amended sites may not be fed to animals for a minimum of four months following the last application event
- turf grown on biosolids amended sites may not be harvested for a minimum of one year following the last application event

Part 503 only contains a prohibition on the application of Class B biosolids or septage on frozen or snow-covered ground and within 10 meters (~33 feet) of a surface water.

To the best of the Program's knowledge, neither Class B biosolids or septage are being used, or ever have been used, on sites producing crops for direct human consumption in Vermont.

Class A biosolids are comprised of sludge which has been subjected to a Process to Further Reduce Pathogens (PFRP) or again, an equivalent process approved by the PEC or the permitting authority. These processes typically entail high temperature aerobic or anaerobic digestion, heat drying, high temperature lime stabilization, or other thermal or chemical treatment processes that result in the reduction of pathogen indicator organism densities to below their test method's detection limits. PFRP methods are, in effect, pasteurization processes designed to virtually eliminate pathogens.

Under Part 503, the set of pathogen indicator organisms that may be selected for Class A demonstrations is expanded from the testing of *fecal coliform* or *salmonella s.p.* densities, the only indicator organisms allowed for Class B demonstrations, to include viable helminth ova (parasitic worm eggs) and enteric viruses under Class A: Alternatives 3 and 4, neither of which include process-based requirements. Of the six Class A Alternative demonstrations established in Part 503, Vermont only accepts the four Part 503 alternatives (Class A: Alternatives 1, 2, 5, and 6) that do include process-based treatment requirements and that do not recognize the use of viable helminth ova or enteric viruses as indicator organisms. Vermont has adopted this approach for two main reasons: 1) the Program believes that in order to further assure pathogen kill, treatment in a process based on a time/temperature relationship or chemical environment necessary to assure pasteurization is requisite, and 2) recent research has shown that the density of viable helminth ova and/or enteric viruses in raw sewage is commonly sufficiently low such that it can meet the Class A standard absent any treatment for pathogen reduction. In other words, the Program believes that a demonstration of the absence of these organisms in treated biosolids, when they might not have been present in the raw sewage, is not a valid demonstration of the degree of pathogen reduction achieved by the process. In fact, EPA itself is considering deleting Class A: Alternatives 3 and 4 from the Part 503 regulation over those same concerns, primarily in relation to the issues surrounding the presence/absence of viable helminth ova and enteric viruses in raw sewage, which can result in the need to seed systems with these pathogen indicators ahead of the pathogen reduction treatment process in order to obtain usable data on the level of their destruction. The Program will not approve any process that requires seeding helminth ova or enteric viruses (or any other pathogen indicator organisms) in order to have sufficient densities in the raw sewage for the ability to make a compliance demonstration in the treated biosolids.

Septage is also managed via land application in Vermont. Under Part 503, septage that may be managed via land application is restricted to *'domestic septage'*, defined in 503.9 as:

> *"material removed from a septic tank, cesspool, portable toilet, Type III marine sanitation device, or similar treatment works that receives only domestic sewage. Domestic septage does not include material removed from a septic tank, cesspool, portable toilet, Type III marine sanitation device, or similar treatment works that receives either commercial wastewater or industrial wastewater and does not include grease removed from a restaurant or grease trap."*

Vermont further restricts what it considers to be domestic septage by specifically prohibiting any cesspool, portable toilet, or Type III marine sanitation device wastes from being managed via land application, primarily because none of these wastes, unlike those contained in a traditional septic tank, has undergone an adequate degree of biological decomposition during their accumulation.

Domestic septage must also be subjected, at a minimum, to a Class B/PSRP pathogen reduction process prior to application to the land and is typically treated via the addition of hydrated lime (calcium hydroxide) by which the pH is raised to a minimum of 12.0 S.U. and held at that pH for a minimum of two hours prior to application. For septage, 40 CFR 503.32 (c)(2) requires only 30 minutes of exposure at this elevated pH (an "operational concession" by EPA to operators of septage land application programs), whereas the VSWMR has retained its historic two-hour standard, which predates the Part 503 regulation and matches Part 503's time requirement for using lime stabilization for pathogen reduction in biosolids. Land application sites used for septage management are subject to the same site use restrictions as are sites used for the management of Class B biosolids.

Under both federal and state regulations, biosolids that have been treated to the Class A pathogen standards and meet the VAR and applicable contaminant standards (503.13 – Table 3 at the federal level or as established in the VSWMRs if produced in Vermont - see Table 3 of this paper) are no longer classified as a solid waste. Such biosolids are commonly referred to as "EQ biosolids" (for Exceptional Quality biosolids – a common misnomer is to call them "Class A biosolids", a term which actually refers solely to the degree of pathogen reduction), and those biosolids and/or products derived from them (such as manufactured topsoil) may be marketed and distributed to the general public for unrestricted use and application to the land without first having obtained a permit to do so from ANR [40 CFR 503.10 (g) and §6-301 (b)(5) of the VSWMR]. The EPA adopted this approach because it believes that the use of EQ biosolids is not likely to be a recurring event on any given parcel of land (thereby minimizing the potential for exceeding the cumulative pollutant loading rates), that biosolids treated to Class A pathogen standards pose minimal risk to human and wildlife health, that biosolids meeting the VAR requirements are not likely to create nuisance conditions or attract vermin, and that attainment of the 503.13 – Table 3 contaminant standards represents a minimal risk to exposed individuals. The VSWMRs have agreed with this concept throughout their existence, and there are currently six municipal WWTFs in Vermont that treat the biosolids they produce to EQ standards and market them to the general public (Lyndon, Middlebury, South Burlington – Airport Parkway, Springfield, Stowe, and Wilmington). One additional facility (Brattleboro) is currently undergoing start-up testing and hopes to be EQ certified by the end of 2018, and one composting facility permitted by the Village of Johnson is currently inactive but which is developing a plan in cooperation with the Lamoille Solid Waste Management District and the Town of Johnson to initially resume operations for use in composting non-sanitary organic wastes (food scraps and yard and leaf wastes) and eventually for biosolids again as well. In addition, there are a number of municipal WWTFs that export some or all of their biosolids to out-of-state facilities for treatment to EQ standards (most Chittenden County WWTFs, Bellows Falls, Bennington, Enosburg Falls, and Hartford).

However, because the VSWMR reporting and recordkeeping requirements, as currently written, only applies to facilities producing biosolids and land applying them in Vermont under an ANR permit (from which EQ biosolids products are exempt), an additional conflict between federal and Vermont regulations exists.

Biosolids or biosolids products that are treated to EQ standards in facilities not located within Vermont may legally be (and are being) imported into Vermont as an unregulated commodity provided they meet either the standards established under Part 503 or the operating permit of the facility in which they are produced, despite the fact that those standards may be less restrictive than the corresponding Vermont standards. Until such time as the VSWMR are revised (or supplanted for residual waste management by a new set of Vermont rules) to include a registration and approval program for out-of-state EQ biosolids using the same standards to which Vermont facilities are held, federal interstate commerce regulations preclude Vermont from prohibiting or otherwise restricting their importation and use. Currently, with no such registration and approval program in place, the Program has no idea of the source, volume, quality, or final uses of imported EQ biosolids and EQ biosolids products. It is a specific goal of this regulatory reform effort to develop and implement such a system. It is important to note that the only way Vermont could prohibit the importation and subsequent use of EQ biosolids and EQ biosolids products without running afoul of federal interstate commerce regulations is via an outright ban on applying any such material to the land in Vermont, regardless of its origin. N.B. – a registration and approval program for EQ biosolids produced out-of-state has been developed and is included in a pending revision of the VSWMRs for promulgation in 2018.

## Current Permitting Requirements

In Vermont, all permitting requirements and procedures for sludge/biosolids and septage management are established under the VSWMRs (with the single exception regarding on-site disposal of material removed from composting toilets or stone removed from failed septic system leachfields, as allowed under the Vermont Wastewater System and Potable Water Supply Rules, cited on page 31 of this whitepaper). EPA – Region 1 is not issuing any permits under their own Part 503 authority for sludge/biosolids or septage management except for facilities in the non-NPDES delegated states of Massachusetts and New Hampshire where EPA issues NPDES permits containing both wastewater effluent limits as well as conditions relating to biosolids management.

The VSWMRs allow for two basic permitting mechanisms: 1) Sludge Management Plans, or 2) Solid Waste Management Facility Certifications (Certifications).

Sludge Management Plans (SMP) are non-expiring, no fee, no public process approvals established under §3-301 of the VSWMR for WWTFs that dispose the sludge they produce at another suitable facility not under their control. Examples include sludge that is sent directly from a WWTF to incineration facilities, landfills, or other biosolids managers who provide secondary management under appropriate permits. SMPs are basic approvals for WWTFs that

are not the end managers of the sludge, and only establish authorized secondary or end management facilities and basic sludge quality monitoring requirements.

Septage haulers who simply pump tanks and dispose of the septage at a WWTF, incineration facility, or transfer the septage to a secondary manager or transporter are only required to obtain a Vermont Waste Transporter Permit for their vehicles (10 V.S.A. §6607a) and to report their activities in accordance with §3-703 of the VSWMRs on a quarterly basis.

Any other means by which a WWTF or septage hauler manages sludge/biosolids or septage must be conducted under the authority of a Certification issued by ANR. These activities would include, but are not limited to: land application of Class B biosolids or septage, any type of processing to produce EQ biosolids for marketing and distribution to the general public, incineration, surface disposal under Part 503 – Subpart C, or storage outside the fenced area of a WWTF.

Certifications, which are valid for a maximum of 10 years, establish site authorizations and requirements for materials and site management practices, pathogen and VAR reduction process conditions and monitoring, media (waste quality, soil chemistry, groundwater chemistry, and plant tissue) monitoring and testing requirements and frequencies, quarterly reporting, and recordkeeping.

## Innovative Toilet Technology

As mentioned in the "Introduction" section of this paper, an in-depth discussion of switching from centralized water-based sewage collection and treatment systems to innovative waterless technologies such as DESAR systems (Decentralized Sanitation and Reuse), ECOSAN, Clivus Multrum, and other related products, is beyond the scope of this paper.

While there are unquestionably numerous advantages (which the Program does not dispute) that could be derived by separating purely sanitary sewage from the flow of other wastewater entering a WWTF and managing them as separate waste streams; absent any monitoring of treatment conditions and testing of the final product for pathogen indicator organism densities, these innovative systems provide no assurance of pathogen kill adequate to allow the unregulated disposal or use of their finished product, other than their claim of compliance with the American National Standards Institute (ANSI)/National Sanitation Foundation's (NSF) Standard 41 (the text of which is only available if *purchased* from NSF and the requirements and standards established thereunder are not presented on any website of these technologies' manufacturers).

Compliance with ANSI/NSF Standard 41 is not recognized as an accepted PFRP process in Part 503, and no attempt has been made by ANSI/NSF or any manufacturers of these systems to obtain a Class A Pathogen Reduction Equivalency Determination from the PEC. EPA determined, and 503.32 establishes, that a minimum temperature of 50$^{o}$ C must be attained for composting biosolids in order to achieve Class A pathogen reduction, yet the website of one major manufacturer of these units proudly proclaims that *"temperatures inside the composting*

*unit never exceed 100°F"* (37.8°C). Secondly, most non-incinerating innovative toilet technologies, primarily composting units, are single cell in design. This means that their design lacks a separate chamber in which the actual treatment process can take place without fresh pathogenic fecal material being constantly added as the unit remains in use. Because the Class A pathogen reduction standards (using Alternative 1 for composting toilets) establishes a time/temperature relationship that must be fully met for the *entire amount* of sludge being treated, which at the minimum temperature of 50°C requires 13.17 days of composting, the constant addition of fresh feces means that the Class A pathogen reduction standard can never be met in single cell composting toilet designs if they remain in use during active treatment. For those reasons, ANR and the VDH agree that the waste removed from composting toilets that are not operated in compliance with the requirements of Part 503 for Class A pathogen reduction must be still be considered to be a pathogenic waste that may only be applied to the land as Class B biosolids under a site specific solid waste management facility certification issued by the ANR or in conformance with §1-922 of the Vermont Wastewater System and Potable Water Supply Rules (see the discussion below).

Modern WWTFs and the regulations under which they must function have provided one of the most effective means of preventing the spread of numerous fecal borne diseases - such as typhoid fever, cholera, dysentery, cryptosporidiosis, hepatitis, and polio; which were pandemic in their occurrence prior to the introduction of centralized wastewater collection and treatment systems and the introduction of antibiotics and vaccines effective against these diseases, and which remain major health concerns in some regions of the world where centralized wastewater treatment is non-existent. Ineffective or improper operation of these innovative systems and the subsequent unregulated management of the material they produce would only serve to counteract the public health benefits provided by traditional WWTFs, the original and primary driver for their construction. Therefore, it is important to note that the treated material produced in these waterless innovative systems, just as with sludge produced by traditional WWTFs, is fully regulated under 40 CFR Part 503 (see 503.1), 40 CFR Part 257, or 40 CFR Part 258 depending on its nature and how the material is disposed. And because these Parts, which in large were developed to provide similar safeguards against disease transmission resulting from solids management, specifically prohibit any state's regulations from being less stringent than the corresponding federal regulation, all non-federal jurisdictions are effectively precluded from regulating the "biosolids" these innovative systems produce less stringently than they regulate biosolids produced by a traditional WWTF. The applicability of Part 503 to the biosolids produced in alternative toilet systems is derived from both the "Purpose and Applicability" language (503.1) of the regulation, which establishes (**emphasis** added):

> *(b) Applicability.* ***(1) This part applies to any person who prepares sewage sludge, applies sewage sludge to the land****, or fires sewage sludge in a sewage sludge incinerator and to the owner/operator of a surface disposal site.* ***(2) This part applies to sewage sludge applied to the land****, placed on a surface disposal site, or fired in a sewage sludge incinerator. (3) This part applies to the exit gas from a sewage sludge incinerator stack.* ***(4) This part applies to land where sewage sludge is applied****, to a surface disposal site, and to a sewage sludge incinerator.*

and the "Definitions" section (503.9) of the regulation where:

*'domestic sewage'* is defined as:

> *"**waste** and wastewater **from humans** or household operations **that is discharged to or otherwise enters a treatment works**";* where,

*'treatment works'* is defined as:

> *"either a federally owned, publicly owned, **or privately owned device or system used to treat (including recycle and reclaim)** either **domestic sewage** or a combination of domestic sewage and industrial waste of a liquid nature"*; and

*'sewage sludge'* is defined as:

> *"the solid, semi-liquid, or liquid **residue generated during the treatment of domestic sewage in a treatment works".***

Part 503 does not provide any *de minimis* threshold or technology exemption for escaping regulation and specifically provides such at 503.3 (b), which states:

> ***"No person shall use or dispose of sewage sludge through any practice for which requirements are established in this part except in accordance with such requirements."***;

where 503.1 (a)(1) provides (in part):

> ***"Standards are included in this part for sewage sludge applied to the land…"***

where neither section provides any qualification or exclusions based on why the sludge is being applied to the land (nutrient value in an agronomic setting, soil conditioning, land reclamation, simple disposal, etc.).

On this basis, it is both ANR's and VDH's interpretation of this specific language in Part 503 that the material produced in such innovative systems may not be applied to the land unless the treatment conditions are established in a permit, are monitored for compliance, and the finished material has been tested to demonstrate that it meets all the applicable standards established under the more stringent of federal or state regulations. Vermont regulations, at §1-922 of the Vermont Wastewater System and Potable Water Supply Rules, do provide a minor exception for the disposal of composting toilet waste that is intended to mimic the landfill disposal provisions of Part 257, by providing for on-site disposal of the material:

*§1-922 Composting or Incinerating Toilets and Greywater Disposal Systems*

*(a) Composting or incinerating toilets may be approved in place of conventional water carried toilets. Use of these toilets in buildings other than single family residences on their own individual lots, is subject to review related to the adequacy of the particular unit for the proposed use.*

*(b) All waste removed from a composting toilet shall be considered to be pathogenic. The waste material shall be disposed of at a certified landfill, or by shallow burial in a location approved by the Agency that meets the minimum site conditions given in section 1-805 of these Rules.*

Even if the manufacturers of these alternative systems were to obtain a PFRP equivalency determination from the PEC, the unrestricted use of the "biosolids" they produce under any permitting authority would not be sufficiently protective of human health unless specific monitoring, testing, and reporting protocols were also established and required, as most of these innovative technologies require faithful on-going maintenance by their owner/operators in order to maintain and assure their proper function and capabilities to destroy pathogens. Alternatively, the wastes removed from composting toilets may only be disposed by bagging the material and disposing of it in a landfill or by disposal at a WWTF.

The Rich Earth Institute in Brattleboro, VT, is currently conducting pilot testing operations of technologies to turn urine collected from urine diverting innovative toilet designs into a usable fertilizer. This experimental program, being conducted under a National Science Foundation grant and an ANR permit, treats source separated urine that contains no fecal material in a mobile solar pasteurization unit that treats the urine to EQ biosolids pathogen reduction standards by heating it to a minimum temperature of 50$^{o}$C for a calculated temperature dependent period of time; producing a nitrogen rich liquid fertilizer for agricultural use.

## Emerging Contaminants in Biosolids

Wastewater treatment facilities are highly regulated under the CWA and other regulatory requirements. During the 1970s and 80s, source control and industrial wastewater pre-treatment programs, established by USEPA under 40 CFR Part 403, began to limit the discharge of industrial pollutants into municipal sewers, resulting in a reduction of many pollutants in wastewater and, therefore, biosolids (WEF 2004).

The EPA conducted two surveys, in 1982 (the "40 City Study") and 1988 (the "National Sewage Sludge Survey"), to identify contaminants in sludge and to develop information on the fate and effects of priority pollutants in wastewater treatment plants and sludge. This information was used in establishing the Part 503 Rules. Since the promulgation of the Part 503 Rules, studies by the EPA, the Water Environment Research Foundation (WERF) and other agencies have concluded that the Part 503 Rules adequately protect human and environmental health when biosolids management practices established in the rule are followed. For example, a

comprehensive National Academy of Sciences/National Research Council review of the Part 503 Rules in 1996, and again in 2002, concluded that biosolids use on food crops and feed crops presents "negligible risk" when conducted in accordance with federal regulations (NRC 1996). In 2003, after five years of study, including a non-EPA peer review, the EPA determined that dioxins present in biosolids do not pose a significant risk to human health or the environment and elected not to regulate dioxins in land applied sludge (USEPA 2003), although Maine and New Hampshire have established their own state standards for dioxin in biosolids.

During the last decade, however, the technological advances in analytical methods has enabled the detection and quantification of many compounds at very low, previously undetectable concentrations, that are ubiquitous in our environment and that may accumulate in sludge during wastewater treatment. As a result, the EPA conducted a Targeted National Sewage Sludge Survey (TNSSS), collecting samples at 74 randomly selected publicly operated treatment works (POTWs) from 35 states in 2006 and 2007, to obtain updated concentration values for some pollutants previously evaluated and to obtain information on whether certain contaminants of emerging concern (CECs) may be present in sludge and at what levels. The EPA analyzed sludge samples for 145 analytes and reported a wide spectrum of concentrations of polycyclic aromatic hydrocarbons (PAHs) and semi-volatiles at the part per billion (µg/kg) scale, flame retardants in the part per trillion (ng/kg) to part per million (mg/kg) range, pharmaceuticals in the part per billion to part per million range, and steroids and hormones in the part per billion to part per thousand (g/kg) range (USEPA 2009b). Lately, EPA has announced that they will perform an update to the TNSSS, commencing in the fall of 2016. The Agency plans to sample the same utilities surveyed in the TNSSS in 2006-2007. This update will include new pollutants such as, but not limited to, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), as well as the same pollutants monitored in the first TNSSS, including metals, triclosan, and others.

Micro-pollutants are often referred to as "contaminants of emerging concern" because the risk to human health and the environment associated with their presence, frequency of occurrence, or source may not be completely known. Examples include pharmaceuticals and personal care products (PPCPs), endocrine disrupting compounds (EDCs) such as organohalogen and organophosphate flame retardants, plasticizers (bisphenol A, etc.), detergent metabolites (alkylphenols, etc.), nano-particles, and natural or synthetic steroids/hormones, as well as pesticides, disinfectants, antimicrobials and other organic contaminants that occur in trace levels in our environment and are commonly derived from consumer products discharged to municipal, agricultural, and industrial wastewater sources and pathways.

The large majority of CECs enter municipal wastewater through bathing, cleaning, laundry, and the disposal of human waste and unused pharmaceuticals (USEPA, 2010). The occurrence of CECs in sludge will depend on the concentration and physiochemical properties of contaminants in wastewater sources, on the extent of industrial wastewater pre-treatment, and on the operational conditions of the wastewater treatment facility. Although WWTFs are designed to reduce the load of organic pollutants and pathogens in treated wastewater discharged to the environment, WWTFs are not designed to specifically remove CECs from wastewater (USEPA 2009, 2010), nor are such contaminants currently regulated in wastewater effluent. Therefore, many organic contaminants enter and leave WWTFs unaltered or incompletely removed and

subsequently enter surface waters (Kolpin et al. 2002, Kinney et al. 2006) like Lake Champlain (Phillips et al. 2009; 2012; Shambaugh 2016). The impact of CECs on aquatic ecosystems has been thoroughly examined and remains the focus of several recent studies (Blair et al. 2013, Rosi-Marshall et al. 2013, Bradley & Kolpin 2013). However, because WWTF influent is partitioned into two components by the treatment process, sludge and liquid effluent, a significant fraction of the total organic contaminants entering a WWTF could reside in sludge, and therefore, biosolids. A notable study by Heidler and Halden (2007) investigated the persistence of the antimicrobial Triclosan in a conventional activated sludge WWTF and concluded that the majority of the compound was partitioned to the solid phase and sequestered into the wastewater residuals. The authors also noted that estimations of aqueous-phase removal efficiencies for wastewater contaminants should not be interpreted as proof that these pollutants are actually being destroyed due to the mere transfer of a significant fraction of the contaminant mass to municipal sludge. Concerns over the effects of Triclosan in the environment and on human health have led the Minnesota legislature to ban the sale of retail consumer products containing Triclosan in that state commencing January 1, 2017.

Roccaro et al (2014) subjected a number of CECs to the risk assessment used by EPA in establishing the Part 503 standards. All CECs examined were limited by Pathway 5 (Biosolids>soil>animal>human). The results of Roccaro's work determined that that regulatory limits (the Risk Specific Concentration, "RSC" in Table 11), if enacted, would generally be several orders of magnitude greater than the maximum concentrations detected in multiple studies. Section 405 of the CWA would therefore prohibit EPA from establishing regulatory limits for the CECs evaluated because their highest expected concentration in biosolids is but a fraction of what the risk-based limit would be set at. Regardless, Roccaro evaluated what is obviously a very limited set of CECs, and the simple fact that none of those evaluated would warrant regulatory limits under the CWA Section 405's restrictions does not in any way suggest that a risk assessment on other CECs would produce similar results. Such an assessment should be performed on as many CECs as possible.

**Table 11. RSC Values (mg/kg, dw) and Maximum Observed Concentrations (mg/kg, dw) of Target PPCPs in Biosolids.**

| Contaminant | RSC Value | Max. Concentration |
|---|---|---|
| Chlortetracycline | 11,919 | 0.043 |
| Doxycycline | 754 | 1.780 |
| Erythromycin | 120 | 0.183 |
| Monensin | 39 | not determined |
| Oxytetracycline | 7,957 | 0.005 |
| Trimethoprim | 520 | 0.133 |
| Tilosyne | 21,441 | 0.005 |
| Carbamazapine | 13 | 0.238 |
| Fluoxetine | 15 | 0.258 |
| Triclosan | 472 | 1.508 |

Similarly, a risk analysis conducted in 2015 by Kennedy/Jenks Consultants for the Northwest Biosolids Management Association, entitled "Biosolids Risk Analysis", examined the levels of exposure to selected CECs in biosolids. The risk analysis evaluated twelve CECs and three pesticides [acetaminophen and ibuprofen (analgesics); Fluoxetine (an antidepressant); 17-α-ethinylestradiol (birth control); bisphenol A (a plasticizer); deca-BDE (a flame retardant); azithromycin, ciproflaxacin, erythromycin-$H_2O$, ofloxacin, and sulfamethozone (antibiotics); triclosan (an antimicrobial); and thiabendazole, endosulfan II, and diazonin (pesticides)] in both Class B and EQ biosolids over four exposure pathways:

- Child exposed while playing in a home garden or lawn fertilized with EQ biosolids compost
- Adult gardener exposed while working in a home garden fertilized with EQ biosolids compost
- Occupational worker exposed while applying Class B biosolids to agricultural land
- Adult hiker exposed while hiking in a forested area fertilized with Class B biosolids (a common use of biosolids in northwestern U.S. reforestation projects)

The results of the risk analysis suggested that the investigated CECs in biosolids are unlikely to result in adverse health effects for the exposed individuals. In addition to the risk analysis, a series of comparative risk calculations and exposure comparisons were conducted to facilitate the communication of risk results. Exposures to CECs in biosolids were also measured against exposure to the same CECs from common activities such as hand-washing, taking a Tylenol for a headache, or breathing household dust. The comparison showed that for the biosolids-derived CEC exposures examined, it would take between a low of 1.1 days (for an occupational worker's exposure to deca-BDE in Class B biosolids) and a high of 90.1 million years (for an adult gardener's exposure to acetaminophen in EQ biosolids) to equal a single day of exposure to the same CECs from other unavoidable everyday exposures or acceptable therapeutic doses (ibuprofen came in at low of 24,507 years under the agricultural worker route up to 454,112 years for the hiker exposure route; triclosan at a low of 216 years under the agricultural worker route up to 9,775 years for the gardener route; and azithromycin at a low of 23,309 years for the agricultural worker route up to 965,819 years for the gardener route).

As part of the Kennedy/Jenks study, wheat grown of biosolids amended sites was also analyzed for more than 80 emerging contaminants commonly found in pharmaceuticals and personal care products. None were detected.

Meanwhile, the EPA continues to conduct biennial reviews of the Part 503 standards for the purpose of regulating new pollutants that may be present in biosolids and to ensure that there are effective and protective management practices in place. However, currently there are no federal regulations requiring the testing of biosolids for the presence of organic chemicals. To help fill the gaps in knowledge regarding the presence of organic chemicals in sewage biosolids, a growing number of studies have focused on emerging contaminants in wastewater effluent and sludge. In 2006, for example, Harrison et al. published results from an extensive literature review of organic chemicals in sludge and reported data for 516 organic compounds grouped into

15 classes. The vast majorities of these chemicals were not on the EPA established list of priority pollutants or target compounds, demonstrating the need for additional surveys of organic chemical contaminants in sludge and, more importantly, to assess the potential risks from biosolids land application to human and environmental health through various pathways.

Neither Part 503 nor the VSWMR establish standards for radionuclides in biosolids. After concluding a study in 2004, the Sewage Sludge Subcommittee of the Interagency Steering Committee on Radiation Standards (ISCORS) issued its report on the occurrence and risks of radionuclides in sewage sludge and sludge incinerator bottom ash. The ISCORS Study report presented the following:

> *As a result of Congressional interest, the Sewage Sludge Subcommittee of the Interagency Committee on Radiation Standards (ISCORS) conducted a survey of radioactive material in sewage sludge and ash and performed dose modeling of the survey results to address these concerns and to estimate typical levels of radioactive materials in POTWs around the country.*
>
> *The survey obtained sewage sludge and incinerator ash samples from 313 POTWs across the country. A total of 45 radionuclides were detected, with 8 radionuclides (Be-7, Bi-214, I-131, K-40, Pb-212, Pb-214, Ra-226, and Ra-228) reported in more than 200 samples. The highest concentrations were observed for I-131, Tl-201, and Sr-89 (all short half-lived medical isotopes). Many samples contained radium and uranium. The survey results represent a single sampling event at the 313 POTWs, and therefore, do not account for seasonal or episodic fluctuations in radionuclide levels. The POTWs participating in this survey were specifically selected for their potential for finding elevated levels of radioactive materials in their sewage sludge or ash.*
>
> *Three overall conclusions that arose included the following: (1) Elevated levels of radioactive materials were found in some sewage sludge and ash samples, but did not indicate a wide-spread problem; (2) Estimated doses to potentially exposed individuals are generally well below levels requiring radiation protection actions; and (3) For limited POTW worker and onsite resident scenarios, doses above protective standards could occur. This was primarily due to indoor radon generated as a decay product of naturally occurring radionuclides, such as Ra-226 and Th-228.*
>
> *Therefore, based on conservative assumptions, there are no cases where the 95th percentile dose exceeds the limit of total radiation exposure of 100 mrem per year to individual members of the general public from all controllable sources as recommended by international and national radiation protection advisory bodies (International Commission on Radiological Protection and National Council on Radiation Protection and Measurements). This conclusion suggests that doses from exposure to radionuclides*

*in sewage sludge and ash are below the current limit of total radiation exposure, based on the ISCORS Survey and Dose Assessment.*

Some basic information regarding the sources, uses, and half-lives of common radionuclides are presented in Appendix 5: Table A-7.

Most recently, in 2016 a prime example of the issues surrounding CEC contamination of biosolids arose which highlights the uncertainties CECs bring to biosolids management. Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) are two fluorosurfactant chemicals that were used extensively in the manufacture of Teflon coatings, commercial products that resist heat and chemical reactions, stain-resistant carpets and fabrics, water repellant clothing and fabrics, paper and cardboard food packaging, and in fire-fighting foams. PFOA and PFOS are extremely persistent in the environment and are resistant to typical environmental degradation processes. As a result, they are widely distributed across the higher trophic levels and are found in soil, air and groundwater at sites across the United States and worldwide and in the blood of most animals. The toxicity, mobility and bioaccumulative potential of PFOA and PFOS pose potential adverse effects for the environment and human health.

PFOA's half-life in water is estimated to be greater than 92 years and in the atmosphere at approximately 90 days, and the estimates for PFOS are greater than 41 years and approximately 114 days respectively (EPA 2014). The half-life of PFOA/PFOS in air is measured in 'days' rather than in 'years', however that is due to atmospheric deposition of the compounds to terrestrial and aquatic compartments (soil and water), not due to their degradation. One recent study (Guerra et al. 2014) has demonstrated that in several commonly utilized wastewater treatment processes that operate at longer hydraulic retention times and higher temperatures, perfluoroalkyl acids, such as PFOA, can actually be created from precursors commonly found in sewage.

PFOA levels in blood are related to increased lipids, uric acid and liver enzymes in the blood, which may or may not lead to effects on an individual's cardiovascular system, kidneys or liver. Studies have also shown a correlation, but not a cause-and-effect relationship, between levels of PFOA in the blood and high blood pressure, decreased birth weight, some immune system effects, thyroid disease, kidney cancer and testicular cancer (VDH 2016). PFOA is classified as "likely to be carcinogenic in humans" by the EPA's Science Advisory Board.

The Program's investigation into the issues surrounding groundwater contamination (and hence numerous private drinking water sources) with PFOA, PFOS, and their associated analogs in a number of Vermont communities has revealed that, in some cases, the sludge produced by the WWTFs serving the contaminated areas is also contaminated with those compounds. It is probable that the contaminants are introduced to the WWTF through the infiltration of contaminated groundwater into sewage collection systems and through the treatment of septage generated at homes in areas where the groundwater (and hence their water supply) is similarly contaminated. For example, sludge from the Town of Bennington's WWTF (the Town is the

locus of the worst contamination in Vermont) has for more than 25 years been composted to EQ standards and distributed to the public for general use. Historically, the composting was conducted in a Town owned and operated facility located at the Town's WWTF and the finished product was marketed and distributed by a third-party vendor both within and outside of Vermont. Following the closure of that composting facility several years ago, Bennington's sludge has been shipped to another biosolids compost facility at the WWTF in Williamstown, MA, where it is also ultimately distributed to the public for general use after being treated to EQ standards.

The primary concerns over PFOA and PFOS in biosolids are the potential for them to leach out of land applied biosolids and subsequently contaminate groundwater that serves, or potentially could serve, as a drinking water supply. Studies have shown that PFOA and PFOS will readily leach out of biosolids and soils, are relatively soluble in water (~9.5 g/L), and do not remain bound to organic matter in biosolids or soils. While research demonstrates that dermal absorption of PFOA and PFOS is minimal and its volatility is fairly low, meaning that mere skin contact with PFOA contaminated biosolids presents minimal risk and the likelihood of excessive exposure via inhalation is also minimal; exposure from drinking contaminated water or from the ingestion of contaminated materials does present potential health risks in direct proportion to the amount of PFOA and PFOS ingested. DEC has recently established new groundwater protection standards for PFOA and PFOS in the Vermont Groundwater Protection Rule and Strategy by setting Enforcement Standards of 0.02 ppb and 0.03 ppb (20 ppt and 30 ppt), respectively, and has established liquid wastes containing PFOA and/or PFOS in concentrations greater than 20 ppt (combined total) as Vermont listed hazardous wastes in the Vermont Hazardous Waste Management Regulations. VDH has also issued a Drinking Water Health Advisory for PFOA and PFOS, which establishes that water having a total PFOA/PFOS concentration of 20 ppt or greater should not be consumed. The Vermont standard is lower than EPA's advisory recommendation of 70 ppt total PFOA/PFOS.

The Program has modelled a "worst case" scenario to estimate potential PFOA/PFOS leaching to a groundwater aquifer after land application of contaminated biosolids. The model represents a "worst case" situation in that it does not provide for any inflow or outflow of groundwater from the confined aquifer, hence there is no dilution derived from groundwater flow beneath the site as would occur in a non-confined aquifer. Although a "typical" single application of PFOA/PFOS contaminated biosolids (for example, 4 dry tons/acre containing 10 ppb PFOA/PFOS and incorporated into the plow layer – typically estimated at 2 million pounds of soil/acre) will result in an expected increase in the soil PFOA/PFOS concentration of 40 ppt, the entire mass ($8 \times 10^{-6}$ lbs) of PFOA/PFOS applied is susceptible to leaching to groundwater. If modeled as a 'worst case scenario' for a one acre, 10 foot-thick, fully- saturated, static confined aquifer with 30% porosity, and full mixing of the entire available mass of PFOA/PFOS is assumed, the amount of PFOA/PFOS in the biosolids would increase the concentration of PFOA/PFOS in the approximately 3.7 million liters of groundwater contained in the aquifer by about 0.0098 ppb (i.e. 9.8 parts per trillion). The Program's investigation into the implications of this matter is an on-going effort and is an excellent example of the challenges that CECs pose to biosolids management and the challenges that very small amounts of CECs can present.

## Transport and Fate of Biosolids Bourn CECs in the Environment

CEC exposure pathways from the land application of biosolids, as reported in the literature, include direct soil consumption by foraging livestock (Fries 1996, Wild et al. 1994), uptake of contaminants into plants consumed by livestock (Wild et al. 1994, Rideout & Teschke 2004, Macherius et al. 2012) and humans (Kipper et al. 2010, Karnjanapiboonwong et al. 2011, Sauborin et al. 2012, Wu et al. 2012), terrestrial bioaccumulation (Kinney et al. 2008, Snyder et al. 2011, 2013), leaching and/or runoff from land applied fields to surface and ground waters (Lapen et al. 2008, Gottschall et al. 2012, 2013, Wong et al. 2012, Yang et al. 2012) and bioaerosol transport from land application operations (Rusin et al. 2003, Pepper et al. 2008, Viau et al. 2011).

The occurrence of organic chemicals in soil and the potential transfer of contaminants through various pathways depend on many factors, including the concentration and physiochemical properties of contaminants in the amendment source, soil type, organic matter content, reduction/oxidation (redox) potential, pH, the pollutant's octanol/water partition coefficient, slope of fields, presence and type of vegetation, rate and method of application, management practices, and climate parameters affecting degradation and off site transport such as temperature and precipitation.

Generally, organic contaminants that survive wastewater treatment are strongly bound to organic matter in biosolids and in biosolids amended soils and are relatively insoluble in water, thus limiting their leaching potential. Gottschall et al. (2012, 2013) reported no significant impact on the quality of either tile drainage or groundwater despite very high rates of biosolids application (~9.8 dry tons/acre) and detection of PPCPs in biosolids aggregates up to one year post-application. The authors reported several mechanisms that limited tile and groundwater contamination, including incorporation of biosolids via tillage, lighter textured soils with fewer macropores, a deep tile drainage system, and limited winter precipitation. However, the same group of researchers (Lapen et al. 2008, Edwards et al. 2009) published very different results from a similar experiment that monitored PPCPs in tile drainage post application of biosolids. Lapen et al. (2008) showed that PPCPs moved rapidly to tile drains via soil macropores and were found in maximum concentrations of 10 to 1,000 parts per trillion (ng/L). The conflicting results between these studies are most likely attributed to different experimental conditions, namely in Lapen et al. (2008): i) the selected PPCPs were spiked into biosolids; ii) biosolids were liquid with very low solids content; iii) soil type was more clayey with macropores (worm burrows) and; iv) the fall application season was wet with frequent and heavy rainfall. In fact, Lapen et al (2008) admits that the conditions of their study represented a 'worst case' scenario in terms of contamination risk from tile drainage.

As with any fertilizer, attention to weather conditions, to application rates, and to appropriate management practices are important for reducing losses of nutrients (particularly phosphorus) and other compounds through runoff or over-application (Pepper et al. 2008). Positive correlations have been reported for rainfall and hormone runoff from agricultural test plots amended with biosolids, but those studies were conducted under simulated conditions of heavy

precipitation replicating 100-year rainfall events 5 days before and 1, 8 and 35 days after biosolids application (Yang et al. 2012). A study of viral contaminant runoff from biosolids amended fields by Wong et al. (2010) also used a simulated rainfall rate that was much higher than natural rainfall rates. Results demonstrated that sandy-loam soils with a vegetative cover can be an effective filter for removing viruses due to virus sorption to biosolids particles and that the depth of the soil profile was an important factor. However, because high rainfall rates saturated the soils and created surface ponding, water samples from ponded water contained viral contamination that, according to the authors, represented a threat to water quality when biosolids were allowed to remain on the soil surface after application. The authors suggest using management practices to reduce runoff potential, including pre-tillage, low application rates, incorporation or injection, and timing of application to avoid wet ground or significant rainfall.

As presented in the "Biosolids Regulation: Federal and Vermont" section of this document, Vermont's regulations address the potential runoff exposure pathway via several mechanisms. Application practices and rates for biosolids and septage are strictly controlled and application of biosolids to frozen or snow-covered ground, or where there is less than 36" of unsaturated soil, is prohibited. Furthermore, minimum isolation distances (Table 9) and site monitoring requirements (Table 8) for land application exceed corresponding federal standards or are established where no federal standards exist.

In addition to research on the potential for runoff of organic chemicals from amended agricultural lands, the uptake of emerging contaminants to vegetation from amended soils has been a topic addressed by numerous research studies. Manure from livestock and poultry is a source of a number of contaminants, including pathogens, hormones, pharmaceuticals, and antimicrobials; and several studies have documented the presence of veterinary medicines in manure amended soils (Kumar et al. 2005, Boxall and Johnson 2006, Dolliver et al. 2007, Bassil et al. 2013). In 2007, the approximately 2.2 billion livestock in the U.S. generated an estimated 1.1 billion tons of manure (USDA 2009), which the EPA estimated to be an amount 13 times greater than all human sewage sludge produced in the U.S. (USEPA 2013). Vermont farms produce and manage an estimated 3.8 million tons of manure annually and ranks #3 out of all U.S. states in the amount of manure generated on a farmland area basis, with an estimated 3.05 tons of manure per acre (USEPA 2013). Almost 34 million pounds of antimicrobials were sold for livestock in 2014 in the U.S. (FDA 2015), an estimated four to five times greater than the amount used to treat human infections (USEPA 2015). The uptake and accumulation of such chemicals into plants is well documented, however, authors report mixed conclusions regarding risks to human health. Kumar et al (2005) found that the uptake of the antibiotic chlortetracycline into plant tissues was small (2-17 ng/g fresh weight) but concluded that there were potential human health risks associated with consumption of fresh vegetables grown in soil amended with antibiotic laden manures. Similarly, Dolliver et al (2007) demonstrated the uptake of the veterinary antibiotic sulfamethazine into corn, lettuce and potato plant tissue, with concentrations ranging from 0.1 to 1.2 mg/kg (dry weight). Although less than 0.1% of applied sulfamethazine accumulated in plant tissue after 45 days of growth, and greater than 70% remained in soil, the results raised potential human health concerns of consuming low levels of antibiotics from produce grown on manure-amended soils. Bassil et al (2013) performed a pot

study in the greenhouse to measure the uptake of gentamicin and streptomycin by carrot, lettuce and radish, reporting that these plants did not absorb either antibiotic in significant quantities except for the uptake of gentamicin into radish root. All three studies (Kumar et al. 2005, Dolliver et al. 2007, and Bassil et al. 2013) found that levels of antibiotics in plant tissue increased with increasing concentration in manure. Boxall and Johnson (2006) also used pot studies with manure amended soils to study uptake of veterinary medicines into carrot roots (tubers) and lettuce leaves. Although exposure concentrations were appreciable in a few instances, accounting for 10% of the acceptable daily intake values (ADI), all were lower than the ADI values, indicating little evidence of an appreciable risk.

Approximately 670 dry tons of Class B biosolids were land applied to about 0.08% of Vermont's agricultural land in 2017 (Appendix 3: Table A-5) and nationally, biosolids are applied to approximately 0.1% of agricultural land (NRC 2002). Yet much of the research on potential pathways of emerging contaminants entering the food chain has focused on uptake and accumulation of pollutants into plants grown on biosolids amended fields. Several of these recent studies are summarized in Table 12.

**Table 12. Literature review of recent studies of plant uptake of emerging contaminants.**

| Conditions | Contaminant | Vegetation | Author Conclusions | Author/Year |
|---|---|---|---|---|
| Hydroponics, spiked test compounds | bisphenol A, diclofenac, naproxen, 4-nonylphenol | Lettuce, collards | Accumulation (µg/kg) greatest in roots, human dietary uptake predicted to be negligible | Dodgen et al. 2013 |
| Hydroponics, spiked test compounds | carbamazepine, salbutamol, sulfamethoxazole, trimethoprim | Cabbage, Wisconsin Fast Plants (B*rassica rapa*) | Human pharmaceuticals can be actively taken up by plants (µg/kg) under hydroponic conditions | Heklotz et al. 2010 |
| Soil pots, spiked test compounds | organophosphates, plasticizer & insect repellant (DEET) | Barley, wheat, meadow fescue, oilseed rape, carrot | High translocation into leaves of meadow fescue (mg/kg), a forage crop. Risk assessment needed | Eggen et al. 2013 |

| | | | | |
|---|---|---|---|---|
| Soil pots, spiked test compounds | carbamazepine, salbutamol, triclosan, sulfamethoxazole, trimethoprim | Chinese cabbage | PPCPs at environmentally relevant concentrations resulted in uptake and plant accumulation (µg/kg) | Holling et al. 2012 |
| Soil pots, spiked test compounds | 17α-ethynylestradiol, triclosan | Bean plants | Uptake and accumulation (mg/kg) greater in plants grown in sand vs clay soil | Karnjanapiboonwong et al. 2011 |
| Soil pots, spiked test compounds | fluroquinolines and sulfonamides | Potato | Uptake into potato (µg/kg) and low adsorption of on soil may contaminate food plants | Kipper et al. 2010 |
| Soil pots, spiked test compounds | Sulfonamides | Pakchoi Cabbage | Uptake into cabbage (µg/kg); microbial degradation in soil mechanism of dissipation | Li et al. 2013 |
| Soil pots, spiked test compounds | galoxlide, tonalide, triclosan | Carrot, Barley, Meadow Fescue | Accumulation (mg/kg) in carrot peel relevant to food chain; intro to food chain via feeding livestock less likely due to low uptake to aerial plant parts | Macherius et al. 2012 |
| Soil pots, spiked test compounds | Triclosan (TCS) | Lettuce, radish, bahia grass | TCS may accumulate (mg/kg) in plants; no toxicity at agronomic application rates | Pannu et al. 2012 |
| Soil pots, spiked test compounds; | Organophosphates, plasticizer & insect repellant (DEET) | Barley, carrot | Organophosphates have a high potential for bioaccumulation | Trapp & Eggen 2013 |

| | | | | |
|---|---|---|---|---|
| model simulations | | | (mg/kg) in crops; reach agricultural fields via biosolids and by atmospheric deposition | |
| Soil pots, spiked test compounds | Carbamazepine, diphenhydramine, fluoxetine, triclosan, triclocarb | Soybean | Uptake of PPCPs (µg/kg) into edible portion of agriculturally important crop; uptake behavior compound specific | Wu et al. 2010 |
| Soil pots, biosolids amended | triclocarban (TCC), triclosan (TCS) | Pumpkin, zucchini, switch grass | Leaves and stems accumulated (mg/kg) TCC and TCS; plant uptake reduced leaching | Aryal & Reinhold 2011 |
| Soil pots, biosolids application | 4-nonylphenol | Wheat, oil seed rape | Rapidly degraded in soil; biosolids enhanced mineralization; low rate of uptake into plant | Roberts et al. 2006 |
| Soil pots, sludge amended | ketoprofen, naproxen, diclofenac, ibuprofen | Wheat, soybean | No detectable uptake even at 2x sludge application rate. Risk of exposure via crops very small. | Cortes et al. 2013 |
| Soil pots, biosolids amended, spiked test compounds | Carbamazepine, diphenhydramine, triclocarb | Pepper, tomato, collard, lettuce, radish | PPCP uptake and accumulation (µg/kg) into plant tissue affected by PPCP physio-chemical properties and interaction with soil | Wu et al. 2012 |

| | | | | |
|---|---|---|---|---|
| Field study, biosolids application | Pharmaceuticals and personal care products (PPCPs) | Wheat | No PPCPs detected in wheat grain planted post high rate biosolids application; no significant impact on quality of tile drainage or groundwater | Gottschall et al. 2012 |
| Field study, biosolids application | PBDEs (flame retardants) | Corn | PBDE soil concentrations increased but corn did not exhibit measurable uptake | Hale et al. 2012 |
| Field study, biosolids application | Pharmaceuticals, hormones, parabens | Tomatoes, carrots, potatoes, sweet corn | Little risk of PPCP uptake into vegetable crops with one year offset between biosolids application and harvest | Sauborin et al. 2012 |

The studies referenced in Table 12 confirm the potential for plants to uptake and accumulate a variety of emerging contaminants in concentrations ranging from parts per billion (µg/kg) to parts per million (mg/kg, dry weight). However, the results and conclusions from the majority of these studies are the outcome of experimental methods that do not reflect actual field conditions and, therefore, must be considered in that context. For example, studies employing hydroponic cultivation (Dodgen et al. 2013, Heklotz et al. 2010) neglect the contaminant-soil and plant-soil interactions that greatly impact contaminant availability to plant uptake. Macherius et al (2012) noted that the use of hydroponic cultivation likely resulted in greater plant accumulation of PPCPs/EDCs due to the absence of chemical sorption to soil organic matter and minerals. It should also be realized that there is absolutely no use for biosolids or biosolids amended soils in hydroponic agriculture, as all required nutrients are supplied by the hydroponic solution and hydroponic systems do not use soil as the growing media; thus rendering studies of chemical uptake into hydroponic crops suspect as to their applicability to biosolids management in conventional agriculture.

Similarly, the majority of the studies above relied on laboratory growing conditions (pot studies) with soils spiked with test compounds as opposed to amending soils with biosolids that contain pollutants of concern (Eggen et al. 2013, Holling et al. 2012, Karnjanapiboonwong et al. 2011,

Kipper et al. 2010, Li et al. 2013, Macherius et al. 2012, Pannu et al. 2012, Trapp & Eggen 2013, Wu et al. 2010). Pannu et al. (2013) warned that using models, empirical equations, hydroponics, and systems not amended with biosolids overestimate the bioaccumulation potential of the antimicrobial Triclosan and may not be applicable for biosolids amended soils.

More appropriate than studies employing hydroponics or soil pots with spiked test compounds are experiments that use soil pots but amend the soils with biosolids (Aryal and Reinhold 2011, Roberts et al. 2006, Cortes et al. 2013, Wu et al. 2012). However, such studies fail to take into account the variations in field conditions when assessing persistence of compounds and potential risks. Chaney et al (1999) warned of the tendency for overestimation of metal uptake by plants when extrapolating from pot studies in the greenhouse to the field. Langdon et al (2012) concluded that using experiments to predict field persistence of compounds in biosolids amended soils may overestimate degradation rates and inaccurately predict patterns of dissipation, although their findings were likely due to the unfavorable environmental conditions for degradation at the location of the field trial. Similarly, Holling et al. (2012) noted that in most studies, uptake of PPCPs has been evaluated under non-standard growing conditions or at concentrations of PPCPs that are elevated relative to those expected in soils amended with agronomic rates of biosolids. It is important to understand the potential uptake of contaminants by crops exposed to environmentally relevant concentrations.

Only three of the studies referenced in Table 12 were performed under actual field conditions where soils were amended with biosolids (Gottschall et al. 2012, Hale et al. 2012, Sauborin et al. 2012). These studies generally demonstrated low risk to human health from biosolids borne PPCPs, PBDEs, hormones and parabens, citing low rates of plant uptake and minimal impact on ground water quality. Even under conditions where vegetables of the family Cucurbitaceae (zucchini, pumpkin) were shown to accumulate the antimicrobials Triclosan and Triclocarb in mg/kg concentrations in leaves and stems, but not the fruit, when grown in biosolids amended soils, the predicted acute risk from direct human consumption was considered minimal (Aryal & Reinhold, 2011). However, it is important to note that these studies represent only a portion of the potential research on plant uptake of contaminants from biosolids amended soils. It is also important to note that more data has been collected for certain chemical classes than for others that may pose greater risk. Metabolites of some compounds can also be of environmental concern and may be converted back to the parent compound once the metabolites reach the environment (Jjemba et al. 2002). Therefore, a disregard of conjugates in studies on plant uptake of environmental contaminants may severely underestimate the extent of uptake into plants and, eventually, the potential human exposure to contaminants via food of plant origin (Macherius et al. 2012).

Another contaminant exposure pathway associated with biosolids land application is through feed crop uptake and bioaccumulation into livestock. In 2004, Rideout & Teschke reported results from a literature review of the potential for increased foodborne exposure to polychlorinated dioxins and furans (PCDD/F), rather than potential health outcomes, when sludge is used on agricultural land. The authors reported a weak correlation between concentrations in soils and concentrations in root crops, leafy vegetables, tree fruits, hay and

herbs, and that in all cases, large increases in PCDD/F soil concentrations were required to achieve a measurable increase in plant contamination. These results suggest that biosolids application to land used for most crops would not increase human exposure. However, a considerably stronger positive relationship was observed between PCDD/F in feed and resulting levels in cattle tissue, suggesting bioaccumulation. Although PCDD/Fs are excreted in milk, no association was found between feed contamination and levels of PCDD/Fs measured in milk. Still, the use of sludge on land used to graze domestic food source animals appears likely to result in increased human exposure to PCDD/F.

Grazing animals may be exposed to contaminants by consuming soil along with fodder; either by eating soil directly or by consuming plants to which soil has adhered (Chaney et al. 1996). Wild et al. (1994) pointed to the key role of PCDD/F transfer into livestock via ingestion of biosolids adhered to vegetation. Fries (1996) reported that cattle may consume an average of 6% of their ingested dry matter as soil but that soil ingestion by lactating dairy cows would likely not exceed 1-2% under normal management conditions. Fortunately, Vermont's regulations address this exposure pathway by prohibiting the grazing of domestic food source animals on biosolids amended sites for a minimum of six months following the last application event.

When biosolids are applied to fields in accordance with such site use restrictions and with pollutant loading limits, risk to human health and the environmental from synthetic organic compounds is minimized by a number of barriers. Chief among these is the fact that the majority of organic compounds that survive wastewater treatment are strongly bound to organic matter in soils and are relatively insoluble in water. For example, PBDEs are strongly sorbed to soil colloids and are relatively immobile in soil, potentially (depending on its degradation rate) remaining conserved in soils for decades or longer (Pepper et al. 2008). More recently, Yager et al. (2014) reported dissipation of CECs in land applied biosolids during weathering at the soil surface by vertical transport into the soil column, but results also showed long-term (> 1 year) storage of persistent CECs in surface soils. Limited mobility of biosolids bound CECs, along with site management practices such as buffer zones, incorporation/tillage and restrictions on application timing; reduce the opportunity for these compounds to move to water bodies.

Furthermore, compared with aquatic ecosystems, terrestrial systems have orders of magnitude greater microbial capability and residence times to achieve decomposition and assimilation (Overcash et al. 2005). Lorenzen et al. (2006) reported that endocrine disrupting compounds in biosolids rapidly degrade following land application and, similarly, Roberts et al. 2006 showed rapid mineralization of the surfactant metabolite 4-nonylphenol in soils under aerobic conditions. It has become generally accepted that only field data from long term studies of environmental contamination sources provide data appropriate for risk assessment and environmental regulation (Chaney et al. 1999). Research has indicated drastic differences in the rate of decomposition of organic compounds between studies examining decomposition rates in biosolids amended field soils and laboratory pot tests. Degradation rate differences are generally attributed to the variations in field conditions present in natural field settings versus what is experienced in laboratory tests. Overcash & Pal (1979), Clark & Smith (2011), Langdon et al. (2012), and

Gottschall et al. (2012) have reported the observed half-lives of a number of organic contaminants in biosolids amended field soils (Table 13).

**Table 13. Half-life (days) of selected organic compounds in biosolids amended soil systems.**

| Compound | Half-life | Publication |
|---|---|---|
| hydroquinone | 0.5 | Overcash & Pal 1979 |
| pyrocatechin | 0.5 | Overcash & Pal 1979 |
| testosterone | 0.5 – 8 | Overcash & Pal 1979 |
| 17β-estradiol | 1 – 10 | Overcash & Pal 1979 |
| phenol | 1.3 | Overcash & Pal 1979 |
| 2,4-methylaniline | 1.5 | Overcash & Pal 1979 |
| polydimethylsiloxanes | 2 – 28 | Overcash & Pal 1979 |
| 17β-ethanyl estradiol | 3 – 10 | Overcash & Pal 1979 |
| acetic acid | 5 – 8 | Overcash & Pal 1979 |
| ibuprofen | 12 | Clark & Smith 2011 |
| quaternary ammonium compounds | 17 – 40 | Clark & Smith 2011 |
| Gemfibrozil | 20 | Clark & Smith 2011 |
| cellulose | 35 | Overcash & Pal 1979 |
| octylphenol | 35 | Overcash & Pal 1979 |
| n-nitrosodiethylamine | 40 | Overcash & Pal 1979 |
| bisphenol A | 43 | Langdon et al. 2012 |
| carbamazepine | 46 | Gottschall et al. 2012 |
| acetaminophen | 63 | Gottschall et al. 2012 |
| organotin compounds | 70 | Clark & Smith 2011 |
| azithromycin | 71 | Gottschall et al. 2012 |
| 4-t-octylphenol | 75 | Overcash & Pal 1979 |
| nonylphenol | 80 | Overcash & Pal 1979 |
| di-n-butyl phthalate ester | 80 - 180 | Overcash & Pal 1979 |
| anthracene | 110 - 180 | Overcash & Pal 1979 |
| synthetic musk compounds | 180 | Clark & Smith 2011 |
| Galaxolide | 180 | Clark & Smith 2011 |
| triclosan | 182 | Gottschall et al. 2012 |
| epitetracycline | 198 | Gottschall et al. 2012 |
| Ofloxacin | 198 | Gottschall et al. 2012 |
| Norfloxacin | 289 | Gottschall et al. 2012 |
| miconazole | 347 | Gottschall et al. 2012 |
| benzo (a) pyrene | 60 - 420 | Overcash & Pal 1979 |
| non-ionic surfactants | 300 - 600 | Overcash & Pal 1979 |
| aminoanthroquinone dye | 100 - 2000 | Overcash & Pal 1979 |
| polydimethylsilicone | 900 - 1400 | Overcash & Pal 1979 |
| polybrominated diphenyl ethers (PBDEs) | 1400 - 7300 | Clark & Smith 2011 |

Table 13 shows that many CECs are degraded relatively quickly in agricultural soils. With the exception of polyhalogenated diphenyl ethers, biphenyls, dioxins, and similar highly stable chemicals; the half-life of most of these compounds is on the order of six months or less. These compounds are all relatively resistant to decomposition in the chemical and biological conditions of the wastewater treatment environment, but all exhibit accelerated degradation rates in soil systems. This is due in large part to the differences in the chemical and environmental conditions that these compounds are exposed to in the two environments. Chemicals which "survive" wastewater treatment, when placed into an agricultural soil media, are exposed to a wide range of new biological and chemical reactions that they were not exposed to in the wastewater treatment process. Additional chemical degradation processes to which these compounds are exposed includes hydrolysis reactions, photolytic reactions, adduct formation, redox reactions, acid/base neutralization, and precipitation, among others. *In situ* agricultural soils also contain populations of a huge variety of aerobic bacteria and other higher organisms that are not present in wastewater treatment operations. These naturally occurring organisms are typically present in densities that are many orders of magnitude greater than those found in wastewater treatment processes, and they provide numerous additional routes of metabolic decomposition compared to those provided by microbial activity during wastewater treatment. The presence of the biosolids matrix seems to affect degradation rates compared to soil on its own. For example, degradation rates for caffeine in soils increased with the addition of aerobically digested sewage sludge. In contrast, anaerobically-treated (i.e. treated in a low oxygen environment) sewage sludge did not accelerate caffeine mineralization (Topp et al., 2006). The degradation rate of the human pharmaceutical naproxen was also reported to be increased by the addition of activated sludge to the soils (Topp et al., 2008b).

In general, chemical concentrations and the risk of exposure to contaminants via biosolids is very low in comparison to other routes of exposure. For example, human exposure to flame retardant chemicals is greatest from household dust (Lorber 2008), and exposure from consumption of vegetables known to accumulate antimicrobials when grown in biosolids amended soils is substantially less than from use of the products in which they were originally contained (Aryal & Reinhold 2011). Furthermore, recent risk assessments published in the American Society of Microbiology's report on "Land Application of Organic Residuals" (2011) indicate that the spread of human pathogens via biosolids show lower human health risk for many microbial contaminants in municipal biosolids than for manures. However, before biosolids application, careful consideration should be given to the types of agricultural products grown and to the optimization of site management practices that limit exposure. Allowing as much time as practical beyond the limits established in the VSWMR between biosolids applications allows for maximum degradation and assimilation of contaminants and the least potential for long term disruption of the soil ecosystem. In addition, biosolids managers should support pollution prevention and other source control programs that promote the disposal of PPCPs and pharmaceuticals by means other than wastewater. WWTF personnel should maximize the potential for biological degradation of organic contaminants by prolonging detention times (Leu et al. 2012) and by using various treatment methods (anaerobic and/or aerobic digestions, composting, and thermal processes). While most of these compounds could potentially be destroyed or removed from sludge by using technologies such as ozonation or activated carbon

filtration (both very expensive from a capitol and operating cost perspective), serious consideration must be given to the appropriateness of the use of these "contaminants" in the consumer products from which they originate.

The Vermont legislature lent serious credence to this position via the passing of Act 188 ("An act relating to the regulation of toxic substances") in the 2014 legislative session, which enumerated a list of 66 chemicals (actually more, as the list includes eight entries such as *"Cadmium and cadmium compounds"*, all of which can include hundreds of individual chemicals) that are considered hazardous to children. However, the listed contaminants are toxic to adults just as they are to children; and either do or have the potential to create toxic effects on other organisms when released into the environment. The Vermont legislature has lent further credence to this position with the introduction of house bill H.268 in the 2017 session which amends the statutory sections of Act 188 (primarily 18 V.S.A. Chapter 38A) to, among other things:

- Remove the phrase "to children" from the name of the chapter.
- Revise the component of "children's product" definition that lists what products are not considered to be children's products (batteries, snow sporting equipment, inaccessible components of consumer products, used consumer products).
- Remove "to children" from the name of the section and in references throughout the Act.
- Require a manufacturers' notice to the Commissioner (for a chemical of high concern) to now include the name of the product containing the chemical and identify whether the product is a children's product, and to provide the universal product code for the product containing the chemical.
- Allow the Commissioner of Health to adopt rules to regulate the sale or distribution of a consumer product containing a chemical of high concern after consultation with the Chemical of High Concern Working Group.
- Create a requirement that manufacturers of a children's product that contains a chemical of high concern to either remove or make a substitution for the chemical or a seek waiver from this requirement, if the chemical is in a children's product that is marketed for use by/to, sold/offered for sale to, or distributed for use by an individual under three years of age, and if the children's product is: mouthable, a children's cosmetic, or made for/marketed to children under three years of age.

Currently, there a number of efforts under way to develop a reliable, repeatable, and scientifically sound method (a Quantitative Microbial Risk Assessment) of directly measuring the impact of biosolids, or more accurately the contaminants they contain, on the health and fertility of agricultural soils. In general, these efforts are centered on the development of a bioassay method that could be used in real time and in *in situ* applications as a compliance tool. While there is no disputing the presence of numerous contaminants in biosolids, the ultimate consideration of policy decisions cannot be based on mere presence. Fortunately, this is one area of research in which EPA has continued to invest funding. Staff at EPA's research facility in Cincinnati, in cooperation with the PEC, have made significant strides in developing a bioassay method that is applicable to biosolids management. Although a final method is still unlikely to be fully developed, tested, and vetted for a number of years; care must be taken to not adopt

currently available screening methods which are wholly inapplicable to measuring the impacts of land applying biosolids. For example, recent research on a soil screening method developed at Duke University serves well to emphasize the need to critically review any claims of a particular method's applicability. In a paper titled "*Determining the Ecological Impacts of Organic Contaminants in Biosolids Using a High-Throughput Colorimetric Denitrification Assay: A Case Study with Antimicrobial Agents",* Holzem et al. (2014) claimed to have modeled the ecological impacts of a few organic contaminants that are often found in biosolids. But the contaminants tested were not "in biosolids" when they were tested and no biosolids or soil was used in the assay. Rather, the researchers used bacterial cultures of "model denitrifiers" that were spiked with fresh samples of the chemicals being tested, a methodology that has repeatedly been shown as non-representative of actual biosolids amended soil characteristics. Conversely, research conducted at the University of California at Davis has tested the impacts on biosolids amended soils containing typical levels of the anti-microbials. That research found:

> *"that the increased N added with biosolids stimulates nitrogen cycling sufficiently to offset any detrimental impacts on the N cycling caused by Triclosan (TCS) at realistic application concentrations. Biosolids contain traces of TCS and other antimicrobials, but, because the chemicals become transformed and bound as they go through the wastewater and solids treatment processes, they are not as available as fresh chemicals added to soil, and their impacts are negligible. Meanwhile, the stimulating effects of the nutrients and organic matter in biosolids demonstrably boost soil microbial activity."*

The Program would readily welcome the development and use of a bioassay method that provides the reliability and assurances required of a demonstration of regulatory compliance.

The only alternative to the management of biosolids via land application or incineration currently available to Vermont WWTFs is disposal in a municipal solid waste landfill. As of this date, in April 2017, there is only one landfill operating in Vermont that is accepting biosolids for disposal – the Waste USA Landfill in Coventry, into which almost 30,000 wet tons (approximately 59,000 cubic yards) of sludge was disposed in 2015 alone. Also, in 2015, approximately 17.5 million gallons of landfill leachate was disposed at three Vermont WWTFs (Barre, Montpelier, and Newport). Aside from the issue of consuming Vermont's very limited landfill capacity with a potentially reusable material, landfill disposal inevitably results in compounding the contentious issues surrounding the management of biosolids due to its impacts on pollutants in landfill leachate. Appendix 2 of this paper presents four tables of analytical data for contaminants in landfill leachates as a typical example. As is evident from Appendix 2: Tables A-1 through A-3, there is a wide range of contaminant types and concentrations present in landfill leachate, and it must be assumed that there are numerous other contaminants for which an analysis was not, or could not, be conducted. Albeit that a significant number of contaminants that were not included in these analytical efforts are relatively innocuous byproducts of the decomposition of other landfilled organic wastes that are extremely amenable to near complete degradation in wastewater treatment processes, Appendix 2: Table A-4 shows that there are numerous compounds found in leachate that are structurally similar to CECs found

in sludge and for which landfilled sludge would be one of the primary sources for leachate contamination. These compounds undergo minimal, if any, degradation in a landfill's anaerobic reducing environment, just as they survived degradation in the wastewater treatment process, indicating that for many classes of chemicals, their leachate concentrations remain the same or may even increase over long periods of time. And, because all landfill leachate generated in Vermont is disposed for treatment at municipal WWTFs that manage their sludge production by landfilling it in the same facilities that generated the leachate, a closed loop is created wherein the mass loading and subsequent leachate concentration of these compounds can significantly increase over time. While this may appear to be a means of containing these contaminants in a closed system, it must be realized that the concentration of these contaminants in leachate will simply continue to rise and that there will be a commensurate decrease in the ability of the WWTF to remove them. Since every pass of these contaminants through the wastewater treatment process results in the partitioning of some portion of the pollutants to the effluent stream, this will inevitably result in a significant increase in the concentration of the contaminants in effluent discharged to surface waters and in the attendant issues that raises with aquatic biota that then receive chronic low-level exposure. For an in-depth analysis of the severe adverse effects on aquatic biota from chronic low level exposure to these contaminants, there is a wealth of research reports available through the U.S. Geological Survey's library catalog.

The continual cycling of leachate to sludge to leachate, along with the contaminants they contain, is likely not sustainable in the long term and may create a significantly larger and costlier problem for future generations of Vermonters to assume. The constant recycling of previously disposed contaminants and the on-going addition of new contaminants into landfills will only result in the ever increasing concentrations of these contaminants in the leachate and sludge. Ultimately, the liner and collection system of any landfill will fail, albeit that is highly unlikely to occur within the foreseeable future. Regardless of the timing, any such failure has the potential to result in the release of copious quantities of leachate and the contaminants it contains to the groundwater. Secondly, as sewage and septage inputs to municipal WWTFs continue to increase towards their design capacities for either flow or biochemical oxygen demand (BOD) removal, WWTFs will have a correspondingly decreasing capacity to accept and treat leachate. Eventually, this will require either upgrades to WWTFs in order to accept the increasing volumes of total flow (at a huge expense to the municipality's sewer rate payers, as well as the generator of the leachate) or increasing transportation distances to WWTFs with adequate capacity to accept the volumes of leachate being generated. Also, when discharged to a wastewater treatment facility, leachates can interfere with ultraviolet disinfection by strongly quenching UV light and it may also contain high concentrations of heavy metals and ammonia that are inhibitory to the biological processes on which WWTFs rely. In order to mitigate these concerns, landfills permitted to operate in Vermont could be required to install and operate a private WWTF to pretreat or fully treat leachate on-site to decrease the BOD concentration, and could also employ a process (examples are carbon filtration, ozonation, or reverse osmosis) to efficiently remove or destroy the large majority of the organic contaminants of emerging concern discussed in this paper that pass through a WWTF, which is primarily designed for the treatment of pathogenic sanitary wastes, without degradation.

## Emerging Concerns for Pathogens

Most land application occurs with Class B biosolids that, by definition, are likely to contain human pathogenic bacteria, viruses, and protozoan parasites (see pages 25 - 26). A comparison of pathogen levels found within biosolids sampled before and after Part 503 was promulgated has illustrated that Part 503 has been effective in reducing public exposure to pathogens relative to before the promulgation of Part 503 (Pepper et al. 2010). However, the Part 503 regulations pertaining to human exposure to pathogens were established through treatment-based standards and through land application guidelines rather than through risk or epidemiological analysis. And although the USEPA continues to support the Pathogen Equivalency Committee, which approves alternative sludge disinfection processes, potential exposure to pathogens from the land application of biosolids has called into question the sustainability of the practice of land applying Class B biosolids.

The greatest amount of uncertainty in quantitative microbial risk assessment is due to a lack of data on exposure and proper assessments of risk from land applied biosolids, particularly for indirect routes of exposure, such as contact with bioaerosols at land application sites or consumption of groundwater that has passed beneath sites (Pepper et al. 2008, 2010). In addition, concerns have arisen about the presence of specific 'emerging pathogens' that could be present in biosolids. An emerging pathogen can be considered any pathogen that increases the incidence of an epidemic outbreak and examples include *Cryptosporidium*, *E coli* O157:H7, Hantavirus, multidrug resistant pneumococci, and vancomycin-resistant enterococci.

To evaluate the sustainability of land application of Class B biosolids, the University of Arizona undertook a study that collected and analyzed biosolids samples from a single WWTF over an eighteen-year period, from 1988-2006. In addition, the same researchers conducted a national study on the incidence of pathogens in anaerobically digested biosolids produced within WWTFs across the US between 2005 and 2008. These two studies therefore represent a large database on the incidence of pathogens in Class B biosolids, including national and historic distributions, and have generated several publications on the presence of and potential exposure risks to pathogens associated with the land application of biosolids.

Pepper et al (2008) analyzed pathogen data collected during the University of Arizona study in an effort to identify potential biological hazards associated land application of Class B biosolids. They reported that both direct risks and indirect exposures via bioaerosols or microbially contaminated groundwater to human health posed by pathogens in biosolids were low. Specifically, the authors reported that while raw sewage was a definitive source of *Staphylococcus aureus*, the organism was never detected in Class A or B biosolids or in bioaerosols resulting from the land application test sites. These results agreed with previous work by Rusin et al. (2003) who showed that biosolids are not a significant source of *S. aureus* exposures or infections in humans. Community risk of infection from *Salmonella* and *Coxsackie virus A21* were also determined to be low at various distances from land applied biosolids, likely due to dilution and natural attenuation of pathogens from environmental factors such as desiccation and ultraviolet light. Ultraviolet light, which acts by rapidly scrambling the

organisms' genetic material – thereby rendering them incapable of reproducing, is a particularly effective antimicrobial to the extent that is commonly employed as the final stage disinfectant of treated wastewater effluent. Occupational risks to biosolids workers were evaluated and found to be low, although higher than community risks due to enhanced duration of exposure and proximity to the site. The authors also concluded that the majority of aerosols, including endotoxins, captured during land application arose from soil sources rather than from biosolids.

The limited transport of pathogens via aerosols may also be due to the binding of organisms to biosolids particles, which would also reduce the potential for microbial contamination of ground water. Work at the University of Arizona showed that viruses are embedded and/or adsorbed to biosolids, likely restricting the mobility and transport of viruses through the soil and vadose zone. These findings are consistent with studies referenced in the previous section of this document (Gottschall et al. 2012, 2013; Wong et al. 2010) and, although Pepper et al. (2008) cites conflicting reports on the effect of organic matter on the transport of pathogens in soil, the authors ultimately concluded that microbial contamination of groundwater from land application of biosolids is unlikely. However, while pathogens absorbed to or embedded within land applied biosolids are less likely to be transported to groundwater, contamination of groundwater or nearby surface waters by microbial pathogens from on-site sewage treatment (septic) systems is always a potential risk to human health. Scandura and Sobsey (1997) studied the survival and transport of a model enterovirus and fecal coliform bacteria in four on-site wastewater treatment systems, reporting that systems with the coarsest (sand) soils and highest water tables (shallowest vadose zones) saw extensive ground water contamination by viruses and other wastewater constituents. Therefore, on-site wastewater treatment systems must be properly sited, designed, installed, operated, and maintained to ensure adequate long-term performance in treating microbial pathogens, and other contaminants in sewage. Similar considerations must, therefore, be afforded for siting land application projects.

The prevalence of antibiotic-resistant bacteria and endotoxins in soil after land application of biosolids was reported by Brooks et al. (2007) and reviewed by Pepper et al. (2008). Soil samples were collected before and for a 15-month period following land application of biosolids and soil bacterial resistance to ampicillin, cephalothin, ciprofloxacin and tetracycline was determined, all showing negligible increases in the percentage of antibiotic resistance bacteria. Similarly, no significant increases in the concentrations of endotoxins in soil were observed.

Additional research conducted at the University of Arizona on potential biological hazards associated with biosolids focused on the regrowth potential of *Salmonella* in both Class A and B biosolids and biosolids amended soil. Pepper et al. (2008) reported regrowth of *Salmonella* following rainfall events during which biosolids became saturated and anaerobic and specified that moisture content greater than 20% was required for regrowth. No regrowth occurred from Class A or B biosolids when the material was added to soil, regardless of saturation. The risks of infection from *Salmonella* in land applied Class B biosolids were low regardless of exposure route (ingestion or inhalation of aerosol), however, risks from ingestion or aerosol inhalation of Class A biosolids following regrowth in the initial biosolids was significant. Therefore, practices

such as covering stored biosolids and avoiding saturated anaerobic conditions should be required for generators and distributors of biosolids.

As part of the University of Arizona evaluation of the sustainability of land application of Class B biosolids, the long-term effects of land application on soil microbial properties was also reviewed by Pepper et al (2008). Twenty years of annual biosolids applications to replicated field-plots demonstrated a lack of adverse effects on soil microbial numbers. In fact, land application increased microbial diversity and enhanced microbial activity. These results are in accordance with Snyder et al. (2011) who found that biosolids borne Triclosan had no effect on soil microbial community respiration or ammonification up to the greatest concentration tested. Interestingly, reports from research on aquatic systems have shown a correlation between Triclosan concentrations in stream sediments and the number of benthic bacteria resistant to Triclosan (Drury et al. 2013). Analysis also indicated that Triclosan in sediment resulted in decreased benthic bacterial diversity and shifts in community composition. Such a comparison lends support to the argument that terrestrial systems have orders of magnitude greater microbial capability and residence times to achieve decomposition and assimilation of potential contaminants in biosolids (Overcash et al. 2005).

The University of Arizona's historic data set revealed no evidence of long term persistence of enteric pathogens in the soil. After 20 years of biosolids application, no known pathogens were detected in soils sampled nine months after the last biosolids application (Pepper et al. 2008). Furthermore, the review of the national data set showed that emerging pathogens such as *Campylobacter* and *E. coli 0157:H7* were never detected in mesophilic anaerobic digested biosolids, and *Shigella* was only detected occasionally (Pepper et al. 2010). This is not to say that risks to human health are zero, and the same authors report that adenoviruses may be more commonly present in Class B biosolids than enteroviruses, but overall, researchers from University of Arizona concluded that the risks to human health posed by pathogens within biosolids are low if current USEPA regulatory guidelines are followed.

A more recent collaboration between University of Arizona researchers and the USDA (Brooks et al. 2012) resulted in the first study comparing biosolids to manure microbial risks. Researchers used quantitative microbial risk assessment to estimate pathogen risks from occupational and public exposures during scenarios involving soil, crop and aerosol exposures. *Campylobacter jejuni* and enteric viruses provided the greatest single risks for most scenarios and the highest risks were associated with both manures and biosolids during and immediately after application. Comparison by pathogen group confirmed greater bacterial risks from manure whereas viral risks were exclusive to biosolids. A direct comparison of shared pathogens resulted in greater risks for manure. All pathogen risks decreased with treatment, attenuation, dilution and time between land application and exposure and nearly all risks were insignificant when using a four-month harvest delay for crop consumption.

Similarly, Viau et al (2013) performed a risk assessment of pathogen exposure, concluding that other than accidental ingestion, the highest public risks of infection from land application are associated with aerosol exposure. The authors admit that there is large uncertainty in aerosol risk

values, due to limitations in current exposure models, pathogen content, and dose-response information. Ultimately, the authors concluded that a rigorous biosolids pathogen treatment process, rather than extending community separation distances, is the most efficient method for reducing pathogen exposure and infection risk.

## Reported Adverse Impacts on Human and Animal Health

Nationwide, over the past twenty to twenty-five years, there have been several hundred reports of adverse impacts on human health and quality of life which were purported to have resulted from exposure to Class B biosolids. The Program is not aware of any such incidents related to the use of properly stabilized EQ biosolids, although there have been three incidents of extremely noxious odors resulting from the use of poorly stabilized EQ compost and heat dried biosolids in Vermont.

The Program is aware of only one incident reported in Vermont in which adverse health impacts to humans were alleged to possibly have been caused by exposure to Class B biosolids. That single incident involved attendees at the multiday concert festival by the band Phish that was held on the grounds of the Newport State Airport in the summer of 2004. Agricultural fields surrounding the runways at the concert site had been used for more than a decade for the management of biosolids generated by the City of Newport's WWTF. All applications of biosolids had been conducted by subsurface injection at a depth of approximately 12 inches, with the last application having occurred some eleven and one-half months prior to the concert. The permit for the concert specified that the areas to which biosolids had been applied were to be used only for parking and that camping in those areas was not permitted. However, heavy rains during the event turned the entire festival site into a sea of mud, leading many attendees to abandon the designated camping areas and camp in or near their vehicles. Regardless, the site management practices, the use of subsurface injection (which leaves no biosolids on the soil surface), the fact that a corn crop had been grown and harvested on the sites in the intervening period, and the duration of time since the previous application event all suggest that concert attendees were exposed to minimal, if any, biosolids. Rather, all evidence examined by the Program and the VDH indicated that the health impacts reported by festival attendees (primarily skin rashes and gastrointestinal distress) were more likely derived from exposure to raw sewage that occurred as a result of two situations. First, the weather conditions made it impossible for pumper trucks to access the portable toilets for maintenance, causing all toilets to overflow and contaminate the ground in the area around them. The other major exposure occurred when gate crashers toppled a perimeter security fence, knocking over an entire row of full-to-capacity portable toilets that discharged their contents onto the ground, which subsequently became distributed throughout the festival site by people walking through the spilled sewage after the units were righted and immediately put back into service at the same location without any remediation of the spilled contents.

In general, the complaints of adverse health impacts resulting from Class B biosolids management predominantly include mucous membrane and eye irritation, respiratory and gastrointestinal distress, headaches, and skin rashes – although more serious effects have been

alleged. Residents also report nausea derived from noxious odors and interference with their quality of life and beneficial use of their property. Typically, these incidents are reported by persons residing within about one-half mile of sites on which undigested, lime stabilized biosolids or poorly prepared anaerobically digested biosolids have recently been spray applied in liquid form without incorporation into the soil.

Odors are the most frequent cause of complaints surrounding land application. Historically, odors were dismissed as purely esthetic or quality-of-life issues. However, Schiffman et al (2004) reported evidence that exposure to odor-causing chemicals can cause illness and that some airborne contaminants can cause a variety of symptoms including eye, nose, and throat irritation, headache, nausea, diarrhea, hoarseness, sore throat, cough, chest tightness, nasal congestion, heart palpitations, shortness of breath, stress, drowsiness, and alterations in mood. Schiffman's findings correlate well with those of Harrison et al (2002), who characterized symptoms of 328 people who related their ailments to the land application of biosolids. These tend to be very similar to the symptoms anecdotally related by residents alleging health impacts from land applied biosolids as well. Eliminating one potential source of noxious odor conditions was the primary driving rationale for Vermont having prohibited on-site storage of biosolids destined for land application other than for very short-term staging in preparation for a land application event.

Poor anaerobic digestion of sludge, unquestionably, will often result in nuisance odors derived from reduced sulfur compounds and mercaptans. Raising the pH of undigested sludge or septage to greater than 12.0 S.U. in order to attain the pathogen reduction requirements via lime stabilization, increases the potential to produce copious amounts of gaseous ammonia and other malodorous amines. Far too often, lime stabilized biosolids or septage are delivered and applied to sites without a sufficient post lime addition holding time and the materials are still off-gassing ammonia and other malodorous compounds. For septage, the primary reason behind the VSWMR continuing its requirement for holding septage at a minimum pH of 12.0 S.U. for two hours, rather than adopting the 30-minute hold time established in 503.32(c)(2), was to provide additional time for the reactions that produce malodorous compounds to abate. Because there is minimal hold time to allow the gas producing reactions to subside and for the gasses to dissipate prior to the biosolids or septage being applied to the land, the immediate area around such sites can be negatively impacted. This problem can be further exacerbated if such biosolids or septage are applied on windless days or under thermal inversion atmospheric conditions that tend to trap air emissions at ground level in localized areas.

Composted and heat dried biosolids also present the potential to generate noxious odors. Compost typically requires a minimum thirty-day curing period following active composting in order to allow the biological decomposition to subside and for the compost to cool to ambient temperatures. During active composting, the potential to generate noxious odors due to the production of volatile fatty acids, amines, terpinoid compounds, mercaptans, and reduced sulfur compounds can be heightened depending on the composting technology employed and on the actual composting conditions. Odorous compounds are usually contained in the mix during the active composting cycle, which must be long enough to assure decomposition to the greatest

extent feasible, and during the curing cycle that allows the odorous compounds to dissipate as the biological decomposition decreases. However, if the active composting or curing cycle is inadequate or not provided, even EQ biosolids will have the potential to create nuisance conditions. Odor problems from heat dried biosolids generally arise when they are surface applied without incorporation and become rehydrated by precipitation.

Three such incidents have occurred in Vermont in the past 25 years, the last in 2016. Two of these incidents involved the importation of composted EQ biosolids produced in Springfield, MA, at a facility which, at that time, was composting undigested sludge without any curing cycle. In both cases (one in Tunbridge in 1998, the other in Danville in 2001), the stockpiled "biosolids" were still undergoing active biological activity and were hot to the touch, despite having met the minimal requirements of Part 503 (which does not require a curing cycle) for composted biosolids. These materials were producing copious quantities of highly malodorous amines and volatile fatty acids and both were being managed in locations that trapped those odors in valleys, resulting in particularly nauseating odor problems and a large number of complaints to the Department. In both cases, DEC ordered the immediate removal of the offending material and reached a voluntary agreement (albeit under the threat of an enforcement action if it were to recur) with the managers of the compost (different ones in each case) that they would never again import that material into Vermont. Most recently, in the spring of 2016, heat dried (not composted) EQ biosolids from Quincy, MA, were surface applied without incorporation to fields in Weathersfield. Those biosolids became rehydrated by precipitation which caused odors to generate which subsequently resulted in numerous odor complaints. The Program successfully worked with the vendor of the material to mitigate the odors. The Program, through its facility permits, has virtually eliminated odor issues with composted EQ biosolids produced by Vermont facilities by tightening the conditions of active composting and by requiring a minimum thirty-day curing cycle and temperature reduction to ambient temperatures before it may be released from the facility. However, note that the lack of regulatory oversight for EQ biosolids produced at out of state facilities and imported into Vermont (see the discussion on pages 30 - 31) leaves DEC with little but local nuisance ordinances and state nuisance air pollution regulations as enforcement mechanisms to address these types of odor problems.

Gastrointestinal complaints are more difficult to relate to a specific causative agent as they may result from exposure to biosolids derived airborne pathogens and noxious odors, as well as from naturally occurring exposure to the myriad of other pathogens in the environment that are not associated with the management of biosolids. Although research at the University of Arizona (Rusin et al 2003, Pepper et al. 2008, Brooks et al. 2005; 2012) has found little risk from potential pathogenic content in aerosols collected downwind of biosolids application events, the potential for exposure of residents in the immediate area cannot be entirely discounted. A review of available literature indicates that gastrointestinal complaints tend to generally be clustered around sites where liquid biosolids were spray applied under windy conditions that had a strong potential to transport aerosols off site. However, most of the causative biological agents are also relatively ubiquitous in the environment, making a definitive determination of the source tenuous at best. If an application event was also associated with exposure to noxious odors, there appears

to be a relatively strong correlation with the number of gastrointestinal ailment reports, again making it more difficult to determine if the ailment is pathological in nature or derived from the adverse effects that noxious odors can have on certain members of the general population.

There have also been allegations that exposure to biosolids has been correlated to ALS (Lou Gehrig's disease), AIDS, cancer, Creutzfeldt-Jakob disease, mad cow disease, and several other uncommon serious diseases. All these purported linkages have been investigated by a number of health organizations (the Centers for Disease Control (CDC) and Mayo Clinic, among others) who have found no demonstrable evidence of any correlation.

At least four human deaths since 1990 have been the subject of allegations purportedly linking them to exposure to pathogens from the land application of Class B biosolids. In 1991, Shayne Connor of Greenfield, NH, died from what was diagnosed as unspecified 'community pneumonia' less than 24 hours after being hospitalized. Mr. Conner slept in a room at his parents' home where he kept the window open at night, and which was near fields where Class B biosolids had recently been heavily surface applied without incorporation. Numerous other residents of the neighborhood also complained of respiratory ailments following the application. Although an autopsy was unable to determine the cause of death, and the coroner who performed the autopsy said there was no evidence to suggest sludge toxins contributed to Mr. Conner's death, the family settled out of court with the company managing the site for an undisclosed settlement and no admission of culpability. In 1994, Tony Behun of Osceola Hills, PA, rode his dirt bike in a field to which Class B biosolids had recently been surface applied without incorporation. Mr. Behun became ill a few days later with flu-like symptoms that persisted for a week before he was admitted to a local hospital and eventually airlifted to Pittsburgh's Allegheny General Hospital where he died of what was diagnosed as a staphylococcus (*S. aureus*) infection. The Pennsylvania Department of Environmental Protection (DEP) found no medical or scientific evidence that Mr. Behun's death was linked to contact with biosolids and the CDC was not asked to investigate the biosolids/disease correlation until 1999, by which time it was impossible to determine if such a correlation existed. In 1995, Daniel Pennock of Berks County, PA, died after contracting both rotavirus and *Staphylococcus* infections allegedly from exposure to land applied Class B biosolids on a local farm. Official interim and final reports by the Pennsylvania DEP pointed to violations by the land-applier for this site, including improper storage and stabilization of biosolids, as well as surface application without incorporation. However, these reports, as well as the subsequent investigation by the EPA, concluded that a source of the viral staph pneumonia could not be determined, and that available evidence did not establish that Mr. Pennock actually had any contact with either biosolids or the land on which biosolids had been applied. In 2003, Michael Seth Jones of Erwin, TN, a farm hand who had participated in the application of Class B biosolids to his employer's fields, died of multiple causes. During autopsy, a biopsy of lung tissue matched bacterial DNA with species present in biosolids (the specific species were not cited in the available report of the incident).

With the exception of the case of Mr. Jones, these claims were cited as evidence in a 2003 petition by Center for Food Safety et al. to EPA entitled "Petition Seeking an Emergency Moratorium on the Land Application of Sewage Sludge". In its response to the petition, the EPA

strongly denied the claims of adverse health effects, citing anecdotal evidence and stating that no causal connection whatsoever was established between the deaths of Shayne Conner, Tony Behun or Daniel Pennock and exposure to land-applied sewage sludge (US EPA, 2003b). Ultimately the EPA concluded that the facts presented in the petition did not support the petition for a moratorium on land application of sewage sludge.

The land application of biosolids has also alleged to have been contributory to several instances of severe adverse impacts on farm livestock. The most notorious case involved two dairy farmers, Andrew McElmurray and William Boyce, in the Augusta, GA, area who alleged that biosolids produced by the Messerly Wastewater Treatment Plant in Augusta were responsible for the death of nearly 500 head. Evidence introduced in court indicated that concentrations of cadmium, arsenic, and PCB in the "biosolids" far exceeded all regulatory standards, and that the concentration of thallium, a pollutant that is highly toxic to cattle but not regulated under federal, Georgia, or Vermont biosolids standards, was dangerously elevated. The court also found that the City's wastewater and sludge management programs were in a shambles, that records were incomplete and likely falsified, that sludge was applied to the sites far in excess of agronomic and cumulative pollutant loading rates, and that the City failed to maintain the sites' soil pH in the proper range (United States District Court, S.D. Georgia, Augusta Division, 2008). This was a situation highlighting what can go wrong when the regulatory frameworks and standards and required management practices are not observed and gross mismanagement occurs.

Two other notable cases of alleged adverse health impacts on herds and the resident farmers involved the farms of Jim Bynum, outside of Kansas City, MO; and the Zander farm in Lynden, WA. Both Mr. Bynum and the Zanders have related a large number of herd problems and multiple ailments suffered by members of their families to sludge management at sites on or adjacent to their dairy farms. Again, the evidence in both cases points to these incidents as cases of what can go wrong if biosolids are not appropriately managed. In both of these cases, the adverse effects have been related to groundwater contamination derived from excessive application rates and failure to control soil pH as well as allegations of exposure to other toxic compounds volatilized from the biosolids applied to the sites.

The only case that has been reported to any State agency in Vermont alleging adverse impacts to livestock due to exposure to biosolids involved biosolids produced by the City of Rutland's WWTF and Robert Ruane - a local farmer. Between November 1987 and December 1990, the City applied biosolids to three fields on the Ruane Farm in Clarendon, Vermont. A total of approximately 210 wet tons of sludge (estimated from the 41.7 dry tons reported, extrapolated at 20% solids) was applied to three fields totaling 87 acres at the loading rates and resulting masses of cadmium and lead applied as reported in Table 14.

**Table 14. Ruane Farm: Loading rates (dry tons/acre).**

| Site | Acreage | dry tons/ac applied | lbs/ac Cd applied | lbs/ac Cd limit | lbs/ac Pb applied | lbs/ac Pb limit |
|---|---|---|---|---|---|---|
| 8 | 37 | 19.22 | 0.36 | 4.5 | 11.16 | 268 |
| 8A | 20 | 4.39 | 0.11 | 4.5 | 4.39 | 268 |
| 9 | 30 | 18.09 | 0.32 | 4.5 | 14.10 | 268 |

**Table 15. Ruane Farm: Annual application rates (dry tons/acre).**

| Land Application Date | Field 8 | Field 8A | Field 9 |
|---|---|---|---|
| November 1987 | 1.25 | 0 | 0 |
| May 1988 | 2.57 | 0 | 4.47 |
| October 1988 | 0.67 | 0 | 0 |
| November 1988 | 1.26 | 0 | 0 |
| March 1989 | 1.30 | 0 | 0 |
| April 1989 | 0 | 4.39 | 0 |
| May 1989 | 0 | 0 | 2.52 |
| November 1989 | 2.30 | 0 | 0 |
| March 1990 | ***1.30*** | 0 | 0 |
| April- 1990 | ***8.57*** | 0 | 0 |
| November 1990 | 0 | 0 | ***5.55*** |
| December 1990 | 0 | 0 | ***5.55*** |

The annual application rates to each site appear to be lower than the expected annual nitrogen based agronomic rate for a corn crop (typically about 5 to 6 dry tons biosolids/acre), with the exception of the combined March and April 1990 applications to Site #8 and the combined November and December 1990 applications to Site #9 (bold italic highlight in Table 15); which, under most scenarios, would *suggest* that the agronomic rate was exceeded.
However, it was not possible to calculate an accurate application rate to verify or refute that notion for any of these events, as it is not known if additional nutrients were being applied to the sites from manure and/or chemical fertilizers in those and the preceding three years (or at what rate, if they were), and the nitrogen content and speciation of the biosolids and nitrogen requirement of the corn strain that was sown are unknown.

During this period, the cadmium concentration in the sludge averaged 9.03 mg/kg, dry weight, within a range of 5.6 – 18.7 mg/kg, dry wt.; and the lead concentration in the sludge averaged 382.5 mg/kg, dry wt., within a range of 49.8 – 791.0 mg/kg, dry wt. All cadmium concentrations met all former and current regulatory standards. The lead concentrations never exceeded the federal or Vermont regulatory standards in effect at the time (1000 mg/kg, dry wt.) or the current 503.13 – Table 1 ceiling concentration of 840 mg/kg, dry wt., but the majority did exceed the current standard (Vermont and 503.13 – Table 3) of 300 mg/kg, dry wt. The Vermont APLR for cadmium (0.45 lbs Cd/acre-year) was never exceeded in any 365-day period during the sites use,

nor was the federal APLR for lead (18.67 lbs Pb/acre-year) ever exceeded; and indeed, the total cumulative mass of each pollutant applied to the sites over the three years of their use does not even exceed the annual pollutant loading limits.

In 1988, Mr. Ruane began to notice health changes in his dairy herd. In a proceeding before the Waste Facility Panel (re: appeal of City of Rutland Interim Certification #I9125, 1992), Mr. Ruane testified that his cows acted arthritic, lost weight, aborted calves and wouldn't breed back, and there appeared to be a high mortality rate. In addition, Mr. Ruane testified that the corn crop planted in the spring of 1989 on Site #9 failed after having had 2.52 dry tons/acre of biosolids applied on that field. However, the same seed planted on the other two sites that year produced successful corn crops, despite Site #8 having received an application of biosolids of 1.3 dry tons/acre and Site #8A having received nearly twice the Site #9 loading at 4.39 dry tons/acre. Subsequently, over the next year, relations between the City and Mr. Ruane deteriorated over these and numerous other issues, and the use of the Ruane Farm for biosolids management ceased, with the last applications occurring in December 1990. Since that date, all sludge produced by the City's WWTF has been disposed in landfills.

Investigations of Mr. Ruane's claims were conducted by the Program and the (then) Department of Agriculture, Food, and Markets (DAFM), but only very limited documentation of findings could be located in the Program's files, as the majority were lost during the Tropical Storm Irene flooding of the Program's offices in Waterbury. The remaining information regarding the Program's investigation includes limited soil (Table 16) and groundwater (Table 17) data from that period. All soil data apparently date from post-December 1990 and indicate a *potential* concern regarding the cadmium and lead concentrations in soil, which are slightly higher than the range typical for the soil types present on the sites (the *potential concern* is primarily because no background native soil data for the site could be found for comparison with the biosolids amended soil concentrations). However, the 14.1 lbs Pb/acre calculated to have been applied to Site #9 suggests that the lead concentration of soil in the plow layer on that site would have been increased by about 7 ppm over the original background concentration, whereas the maximum cumulative application rate would allow an increase of 134 ppm in the plow layer soils. As such, it is unlikely that lead or cadmium concentrations in the soils played any influential role in the issues with Mr. Ruane's herd.

However, the few groundwater data available document that the cadmium and lead concentrations greatly exceeded current groundwater protection standards both upgradient and downgradient of the site. Those standards were higher in 1989 than today, and although a copy of the standards in effect in the late 1980s could not be located, the standards in effect by April 1990 were 20 µg/L for lead and 5 µg/L for cadmium, meaning that the lead and cadmium concentrations bold italic highlighted in Table 17 are between 180 and 1,933 times greater than the Enforcement Standards for lead and cadmium in effect by early 1990. Records establishing the definitive location of the monitoring wells could not be located either, although a site plan submitted by the City depicting the approximate monitoring well locations indicates that there were two monitoring wells associated with the sites, both on Site #9. Well 9 East was the upgradient well and Well 9 West was the down gradient well. Again, no pre-application

background groundwater data could be located, the site plan clearly documents that no wells were located on either Site 8 or Site 8A, and no groundwater monitoring data for those sites is in the Program's files. It should also be noted that this area of Clarendon has historically been the focus of investigations and enforcement actions taken by the DEC against several industrial facilities over incidents of illegal waste management and disposal. Residents of North Clarendon, well removed from the vicinity of the Ruane farm, have also engaged VDH to investigate what they perceive to be an unusual cluster of relatively rare cancers in the general area. VDH found that there was not a statistically significant increase in the local cancer rate.

Also relevant to these local health concerns, as they relate to the Ruane situation, is that the General Electric plant located on Windcrest Rd., about ½ mile directly uphill of Site 9 on the Ruane Farm, operated an unlined landfill at the plant's location from 1979 to 1986 in which lead and other metal hydroxide sludges generated by the G.E. facility were disposed, and G.E. was fined $30,000 in 1989 for illegally disposing of lead contaminated wastes at the facility and for discharging lead to the City's WWTF in excess of their permit limits. The impact of those activities on groundwater flowing beneath the Ruane Farm and the potential that they are the source of the lead contamination is unknown, although the presence of significantly elevated lead concentrations in the upgradient monitoring well lends substantial credence to the position that biosolids managed on the farm were not the source. Also important to note is that the lead and cadmium concentrations in the groundwater samples taken from the wells on Site #9 were already several orders of magnitude above standards prior to any biosolids being applied to that site, where the April 1988 lead concentrations were all approximately 17 mg/L and the cadmium concentrations were also elevated, yet biosolids were not present on Site #9 until May of that year (although some biosolids had been both stored in a PVC lined concrete bunker and relatively lightly applied on Site #8, nearly ¼ mile from the Site #9 monitoring wells, in November 1987) – a fact that essentially precludes biosolids as being the source of the groundwater contamination. An analysis of the corn crop grown on each of the sites during the summer of 1989 yielded results that were below analytical detection limits for both cadmium and lead (the detection limits were not reported). Thallium and other uncommon metals of similar toxicity to cattle were not being used by any area industries at the time; so, although not subjected to an analysis for those pollutants, their presence in the sludge in concentrations greater than the low or sub-single digit parts per million range would not be expected.

If Mr. Ruane was watering his herd from a groundwater source on his farm, it is highly unlikely that the ill effects he noted were due to anything except for combined lead and cadmium toxicity from the water supply, the symptoms of which are highly correlated with the effects that Mr. Ruane described in his 1992 Waste Facility Panel testimony.

**Table 16. Ruane Farm: Post-Application and Typical Background Cadmium (Cd) and Lead (Pb) Soil Concentrations (mg/kg, dry wt.).**

| Site | Soil Cd | Background Soil Cd Range | Soil Pb | Background Soil Pb Range |
|---|---|---|---|---|
| 8 | 0.78 | | 22.3 | |
| 8A | 0.75 | 0.55 – 0.85 | 21.0 | 8.1 – 19.9 |
| 9 | 0.88 | | 21.1 | |

**Table 17. Ruane Farm: Concentrations (mg/L) of Lead (Pb) and Cadmium (Cd) in Groundwater Monitoring Wells.**

| Monitor Well | Test Date | Pb | Cd | Notes |
|---|---|---|---|---|
| 9 | 4/26/1988 | ***17.1*** | ***0.43*** | Site #9. Specific well not identified |
| 9 | 4/26/1988 | ***16.5*** | ***1.28*** | Site #9. Specific well not identified |
| 9 | 6/3/1988 | ***< 5.0*** | < 1.0 | Site #9. Specific well not identified |
| 9E | 5/2/1988 | ***17.0*** | < 1.0 | |
| 9E | 5/2/1988 | ***17.0*** | < 1.0 | duplicate of previous test |
| 9E | 4/28/1989 | < 1.0 | < 1.0 | |
| 9E | 4/23/1990 | ***29.0*** | < 0.2 | |
| 9W | 5/2/1988 | ***8.0*** | < 1.0 | |
| 9W | 4/28/1989 | < 1.0 | < 1.0 | |
| 9W | 4/23/1990 | ***< 5.0*** | ***0.9*** | |
| Preventive Action Limit | | .0015 | .0025 | VT Groundwater Protection Standards |
| Enforcement Standard | | .015 | .005 | |

The DAFM investigated Mr. Ruane's concerns regarding his herd's health. The DAFM report, while non-conclusive as to an assignment of cause, did specifically note several issues and deficiencies in Mr. Ruane's operations, including:

- Anecdotal evidence that his farm management was marginal;
- Anecdotal evidence that the cause of the crop failure on Site #9 in 1988 was the result of sowing seed on soil that was too wet;
- Cows were aborting calves and not breeding back;
- The "sick" animal at the farm at the time of the investigation had a number of calving problems, including an infected uterus;
- The herd had a history of foot problems, including elongated toes;
- Silage quality was marginal;
- The recommended feeding program for lactating dairy animals was not being observed;
- The one forage sample analyzed had an elevated copper content, although it was lower than what the NRC considers to be toxic to dairy cattle;
- A cull rate of 50 animals over three years was not unusual (given the size of the herd), as a cull rate of 25% - 30% is the average range; and,

- That Mr. Ruane was a livestock transporter and operated an open herd, whereby numerous head were shuttled on and off the farm.

The report did state however, that not enough testing of forage had been conducted and that the link between the herd's water supply, groundwater contamination, and sludge management should be investigated further. The Program is unable to locate any documentation that these additional investigations were conducted. Other testimony presented to the Waste Facility Panel by Mr. Ruane (also re: appeal of City of Rutland Interim Certification #I9125, 1992) indicated that an autopsy of one deceased cow and blood tests on several other sick cows was apparently conducted at Cornell University at Mr. Ruane's initiative; but again, no reports of the results could be located. It must also be noted that Mr. Ruane claimed a misunderstanding in the information provided to the DAFM investigation team, in that he also testified in the same Waste Facility Panel proceeding that the feeding program he had related was what he provided in each feeding (three times per day) and were not the daily aggregate totals as the report to the Commissioner suggested. The Program has not been able to confirm or refute his testimony.

Ultimately, neither the Program's or the DAFM investigations established any definitive link between the use of Mr. Ruane's fields for biosolids management and the adverse health conditions experienced by his herd, nor were any other causes attributed to the situation.

## Septage

Any regulatory reform for residual waste management must consider the issues surrounding septage management in Vermont. In 2017, slightly less than 38,000,000 gallons of septage was managed in Vermont, of which approximately 99% was pumped from the tanks of Vermont residences. Of that total volume, approximately 6.7 million gallons was managed via direct application to approximately 220 acres of agricultural lands, following stabilization with hydrated lime to achieve the Class B pathogen reduction standard (See Appendix 4: Table A-6).

The average concentration of contaminants in Vermont generated septage, as determined from a continually updated database (current as of January 2017, calculated using the full detection limit for results that are "less than") is provided in Table 18, as are data taken from a larger regional set of analytical results. For the purpose of calculating the remaining useful life of septage land application facilities, the Program takes a conservative approach and uses the highest value from the two data sets.

There is relatively little difference in composition between septage that is directly applied to the land in comparison to the biosolids produced in a WWTF. Although the treatment of sewage and digestion of sludge will result in greater decomposition of the organic components and many CECs due to the higher operating temperatures, septage that has accumulated over a number of years in a septic tank has also undergone anaerobic digestion, albeit at a lower, ambient ground temperatures, and lime stabilization provides essentially the same degree of pathogen reduction as is provided by anaerobic digestion to Class B pathogen reduction standards.

**Table 18. Average Metals Concentrations (mg/kg, dry wt.) and Solids Percentage (%) in Septage from Vermont and Regional data.**

| Metals | Concentration | |
|---|---|---|
| | Regional | Vermont |
| As | 7.56 | 8.60 |
| Cd | 5.34 | 2.75 |
| Cr | 36.94 | 17.17 |
| Cu | 725 | 500 |
| Hg | 1.59 | 1.28 |
| Mo | 30.77 | 14.29 |
| Ni | 30.64 | 18.79 |
| Pb | 75.93 | 36.91 |
| Se | 7.41 | 10.25 |
| Zn | 1113 | 912 |
| % solids | 2.39 | 1.87 |

As an aside, three of the operators of septage land application programs have stated their intention to retire within the next five to seven years. The discontinuance of these three land application programs will entail the termination of approximately 110 acres (50% of the currently approved acreage) permitted for this use. All three facilities are located in areas of the state where the need to utilize other options for septage disposal will entail considerably longer haul distances to facilities that accept septage.

On average, operators of septage land application programs utilize approximately 32% of their maximum permitted application capacity each year. Put into perspective, the volume actually applied if the maximum permitted application capacity were to be used represents loading each of the 220 acres with the approximate equivalent of a 1.7" rain event spread out over about a six-month period. By comparison, the septic system for a four-bedroom home located on soils with midrange permeability, loads the approximate equivalent of a 3" rain event each year to the area of the leachfield – essentially the same as the hydraulic loading of land application sites during those periods of the year when they can be used (see Table 19). Because the amount of liquid applied to a site in each application event is so low, the Program has never observed or been able to confirm a report of the direct runoff of septage from any site since enhanced regulatory oversight was implemented over 25 years ago (the same being true for biosolids land application sites). This is further supported by monitoring that was conducted as permit requirements in the late 1990s both upstream and downstream of septage and biosolids land application sites proximate to a surface water, in both dry and wet weather conditions. Those analyses for bacterial contamination and nitrogen contamination showed no discernable difference in water quality between the sampling locations and in some cases detected greater concentrations upstream of the sites than was found at the downstream sampling points. Because that surface water monitoring provided no consistent results and provided no usable insight into biosolids and septage management, it is no longer required.

**Table 19. Comparison of Typical Permitted Loading Rate (gal/ft$^2$/day) of Various Septage Management Options.**

| Septage Management System | Typical Permitted Loading Rate |
|---|---|
| Direct land application | 0.2 (see Note 1) |
| Single residence leachfield | 2.0 (see Note 2) |
| Indirect discharge leachfield | 0.5 (see Note 3) |

Note 1 – based on full use of a maximum application rate of 70,000 gal/acre-year
Note 2 – single residence of four people, median permeability soils
Note 3 – system design flow >6,500 gal/day, median permeability soils

In developing the future strategy for septage management, regardless of one's position on the issue of its management via direct land application, the greater picture of septage management in Vermont, in general, must be considered. Currently, the capacity of WWTFs to accept septage varies widely in the state. As is evident from the map of facilities presented in Figure 1, there are many areas of Vermont where there is very limited, or no capacity at local WWTFs to accept septage. Only 24 of Vermont's 90 municipal WWTFs accepted any septage in 2017, and a majority of the other 66 WWTFs do not have the infrastructure necessary to accept septage. In addition, many of the WWTFs receiving septage accept only very limited volumes, often only under extenuating circumstances. In 2017, just five WWTFs (Brattleboro, Middlebury, Montpelier, Richmond, and Rutland) accepted 52% of the total volume of septage disposed at Vermont WWTFs; although the greatest potential volume capacity for septage receiving is in the Chittenden County area, the area of the state with the greatest percentage of its population residing and working in areas served by centralized sewage collection systems (apx. 65%). Burlington Main, Montpelier, Newport, and Rutland, accepted 60% of all trucked-in wastes disposed at WWTFs in 2016; and Montpelier and Newport alone received 97% of the nearly 12 million gallons of landfill leachate disposed at Vermont WWTFs in 2016.

In addition, disposal at those WWTFs that even have the capability to accept septage can be severely limited under a number of circumstances. Typically, access for disposal is not available outside of normal weekday working hours, on weekends, and on holidays, posing a significant problem for emergency situations or jobs that must be done on weekends. Also, WWTFs are limited on the total volume of septage and other wastes they can accept on a daily basis due to limited hydraulic and/or BOD treatment capacity, and access is exclusively on a "first come, first served" basis. Therefore, in order to dispose of the approximately 32 million gallons of septage that the septage haulers do dispose at Vermont WWTFs; on a daily basis they have to compete for access under those limitations with the nearly 12 million gallons of landfill leachate, 12.8 million gallons of sludge from other WWTFs, and 1.5 million gallons of other wastes that are disposed annually at Vermont's municipal WWTFs (data from 2016 quarterly reports). These constrictions resulted in approximately 4 million gallons of wastes generated in Vermont (of which approximately 3.1 million gallons was septage) having to be disposed at non-Vermont WWTFs in 2017. And, the approximately 9 million gallons of septage that was managed via land application in Vermont in 2017 would have only exacerbated this problem if land application was not available as an alternative to disposal at a WWTF.

It must also be noted that neither the state or the federal government has any authority to require any WWTF to accept any wastes that do not enter the facility via its municipal wastewater collection system. Although any municipality that received state funding to install septage receiving infrastructure was required under the funding's enabling legislation, 10 V.S.A. §1626a (which was enacted in 1993, amended in 1994 and 2007, and finally repealed in the 2016 legislative session), to permanently reserve 4,000 gallons for each one million gallons of the WWTF's permitted daily flow for septage receivals, any WWTF's primary regulatory obligation is to meet the effluent limits of its NPDES discharge permit and, under federal regulations, a WWTF is empowered to refuse any side-stream wastes on a day-to-day basis in order to maintain compliance with those effluent limits. As such, only a relatively small number of municipalities opted to accept this financing and very little new infrastructure for septage receiving was installed. Regardless, since the total permitted flow of all 90 municipal WWTFs in Vermont is 76 million gallons per day, had every WWTF in the state participated and installed septage receiving infrastructure, only 304,000 gallons of daily capacity would have been reserved for septage management. However, if WWTF's employing treatment processes that are not compatible with treating high strength septage are eliminated from that total, only about 200,000 gallons of daily capacity would have been reserved for septage management.

Both the Northeast Kingdom and the southcentral portions of the state face a severe lack of facilities for septage management. This leaves but two options for the disposal of much of the septage generated in Vermont – land application, or a long transportation distance and cost to the nearest incineration facility or WWTF that will accept the septage. As fuel costs and WWTF operating costs increase, pumping and tipping fees rise at a commensurate rate. Septage haulers, out of necessity, must pass the associated costs of pumping, transporting, and disposing a tank's contents on to the customer. The potential downside of a radical increase in the cost of septage disposal is that homeowners will delay or refrain entirely from having septic tank maintenance done, thereby exacerbating the incidence of septic system failures. This will mainly be driven by the inability of homeowners to pay a sizable lump sum (often $300 or more) to have their septic tank pumped; as opposed to making small monthly or quarterly payments, as is the case with residences that are on municipal sewer systems.

One Vermont municipality, the Town of Londonderry, has addressed this situation by developing and permitting a land application site for the management of locally generated septage. Approximately 150,000 gallons of septage has been managed at this site annually, at a significantly lower cost than would be incurred by transporting it to the next nearest WWTFs that accept septage, in Bellows Falls or Springfield. As a side benefit, the Town's site, which is located on the former cover material borrow area adjacent to the old, now closed Town landfill, has been successfully reclaimed and now bears an excellent vegetated cover which has virtually eliminated the severe erosion that was occurring on the site prior to its reclamation. The availability of land application as a more cost-effective disposal option, which can provide additional side benefits, must therefore be considered.

The Program has long advocated the development of a state-wide program under which owners of septic systems would be billed easily affordable amounts on a regular cycle (monthly or

quarterly), and the fees placed in an escrow account which would then be used to reimburse septage haulers for servicing systems on a regular basis at appropriate intervals.

## Economics

While this paper will forego an in-depth analysis of the economics of sludge and biosolids management, under the belief that adequate protection of human health and the environment is the tantamount goal of any environmental regulations and the ultimate aim of this process, due consideration must be given to cost factors in the overall question of the sustainability of what Vermont's residents can afford and are willing to bear.

In 2017, approximately 12,400 dry tons (~82,700 wet tons at 15% solids) of sludge/biosolids and 37 million gallons of septage was generated and disposed in Vermont at an approximate disposal cost of $18 million (based on $100 per wet ton for sludge/biosolids and $275 per 1,000 gallons of septage), an amount that does not include the cost of preparing the sludge/biosolids portion for disposal. Preparation costs include the operation of digesters, polymers to assist solids removal, dewatering, storage, and analytical costs, among others. It is estimated that approximately 40% of a WWTFs total annual operating cost is spent on solids management. The Program expects a significant increase in sludge production over the next decade as a result of the increased solids production that will result from the need to remove greater amounts of nitrogen and phosphorus from sewage due to the Long Island Sound, Lake Champlain, and Lake Memphremagog TMDLs.

Although DEC has not conducted its own analysis of disposal costs on a state-wide basis, similar studies conducted by CSWD, the Center for Rural Pennsylvania, and a New Hampshire legislative commission resulted in relatively comparative cost estimates which can provide insight within a regional context (Table 20).

The studies conducted in New Hampshire and Pennsylvania were intended to examine the costs of various disposal options – primarily land application, landfilling, and incineration. The CSWD data are slightly different in that they compare the cost of landfilling and the cost of disposal via shipping to the Grasslands Facility in Chateauguay, NY, for additional processing to EQ biosolids standards.

**Table 20. Comparative cost ($US) of sewage sludge disposal options (per wet ton).**

| Management | New Hampshire | Pennsylvania | CSWD (VT) |
|---|---|---|---|
| landfill | $75 | $75 | $94 |
| land application | $40 | $62 | $130 (Class A)<br>$100 (Class B)<br>$90 (Grasslands) |
| incineration | $71 | $71 | No Data |

Although the Pennsylvania study did not examine the comparable costs for septage management, this issue was examined in detail by the New Hampshire Commission's report to the legislature, which found a similar differential between land application and disposal at a WWTF. Based on tipping fees alone (i.e. – the per gallon cost, exclusive of transportation costs, other business costs, profit margins, etc.), the New Hampshire study found that disposal at a WWTF was approximately $78 per 1,000 gallons and that disposal via land application was at a cost of approximately $25 per 1,000 gallons.

Obviously, a direct comparison of disposal costs across the region cannot be made from these data. This is primarily due to regional variations in landfill and WWTF tipping fees, variations in fuel costs and haul distances, state and local taxes and fees, etc. However, the cost of the various management options relative to each other are consistent in these cases and with anecdotal information gathered from other areas around the country. In general, it appears that land application can provide a distinct cost advantage over landfilling and incineration as management strategies. The New Hampshire and Pennsylvania studies also documented that there is a distinct economy of scale associated with land application, where its cost advantage over other disposal options varies in direct proportion to the volume of biosolids that are being managed. In Vermont, this cost differential is not expected to be as great as in other jurisdictions, primarily due to the costs added by the management practices and monitoring requirements imposed on land application under Vermont's program that are not required in most other jurisdictions. These requirements, though not completely unique to Vermont, include: more frequent analyses of biosolids; groundwater, soil, and plant tissue testing; a ban on field storage of biosolids (meaning that a storage facility located at the WWTF is necessary); requirements to incorporate biosolids into the soil following application; etc. Although these practices do reduce the cost differential between land application and other management strategies, the Program considers them essential to assuring the integrity and scope of its oversight. As such, the Program does not recommend any relaxation of the monitoring required of land application programs, other than eliminating the requirement to perform the Toxicity Characteristic Leaching Procedure (TCLP) analysis which is wholly unsuited to an analysis of the biosolids matrix.

An additional cost of solids management in Vermont comes through the imposition of the Franchise Tax on Waste Facilities. This tax, of $6 per ton of solid waste disposed, is authorized under 32 V.S.A. 5952, with certain exemptions being provided in 32 V.S.A. 5953. The exemptions provide that sludge wastes delivered to a recycling or composting facility or septage or sludge delivered to a facility other than a landfill or incinerator are not subject to the franchise tax. As such, biosolids that are managed via land application or treatment to the EQ biosolids standards are exempt from the tax. Sludge that is mixed with soil and used as cover material at a landfill is considered to have been applied to the land and is also exempt from the tax. A prohibition on the land application of biosolids and corresponding switch to solely landfill disposal would result in the need to landfill approximately 65,700 wet tons (approximately 197,000 $yd^{3)}$ of sludge annually, thereby consuming approximately 6% of Waste USA's remaining capacity each year, and would increase disposal costs by about an additional $645,000

per year (based on 2017 disposal rates) in solids management costs across the state, as the Solid Waste Franchise Tax is assessed on the wet tonnage of biosolids disposed.

In early 2015, the CSWD conducted a detailed analysis of various means of managing biosolids produced by the WWTFs in its member's towns. CSWD is the sole solid waste management district in Vermont that has assumed overall responsibility of biosolids management. CSWD conducted a broad examination of the pros and cons of various technologies, including the economics of each, in its evaluation of how to best manage this waste stream in the future. CSWD's April 2015 report (which is not available on-line) of the study's findings provided the following data in Table 21:

**Table 21. Sludge Management Options, Benefit, and Cost ($/ wet ton) in Vermont**

| Management Option | Benefit | Cost |
|---|---|---|
| liquid sludge → dewatering → landfill | • none | $94 -$98 |
| liquid sludge → dewatering → Casella Grasslands facility | • land applied as EQ | $90 |
| liquid sludge → dewatering → thermal drying | • land applied as EQ | $200 -$285 |
| liquid Sludge → dewatering → thermal drying → gasification | • produces methane usable as fuel | $300 -$350 |
| liquid sludge → dewatering → composting | • land applied as EQ | $110 -$175 |
| liquid sludge → dewatering → alkaline stabilization | • land applied as EQ | $100 |
| liquid sludge → mesophilic anaerobic digestion → dewatering | • land applied as Class B<br>• produces methane usable as fuel | $130 -$150 |
| liquid sludge → thermophilic anaerobic digestion → dewatering | • land applied as EQ<br>• produces methane usable as fuel | $140 -$160 |
| liquid sludge → mesophilic anaerobic digestion → thermophilic anaerobic digestion → dewatering | • land applied as EQ<br>• produces methane usable as fuel | $110 -$130 |

## Management Alternatives

In Vermont, infrastructure for residual waste management is currently provided only by municipalities and private sector generators, there is no federal or state owned or operated infrastructure. Limited state funding is available to municipalities that construct new biosolids management infrastructure as part of a WWTF upgrade, but no such public funding is available to the private sector generators or residual waste managers. The Program does not promote the implementation of any specific technologies or management strategies beyond what is mandated in order to achieve compliance with the requirements of the CWA. In general, while the Program will assist municipalities and private entities in the evaluation of upgrades or new

infrastructure involving currently standard or emerging technologies for their ability to meet the proponent's claims, environmental and health safety concerns, and compliance with and ability to meet all regulatory standards; the Program refrains from promoting or mandating one technology over another.

In summary, there are only three broad basic means by which biosolids can be managed or disposed: land application, landfilling, or incineration – although there are a variety of specific technologies within each of those categories. The use of some emerging technologies such as pyrolization (gasification), thermal drying, ozonation, etc., all result in the production of their own waste streams or final products that must still be managed via one of the three basic options. There are no incineration facilities in Vermont and it is unlikely that one could be sited here given their sordid history in the state. The CSWD built a heat dryer and pelletizing facility in South Burlington in the mid-1990s. The operation of that facility was very short lived due to significant odor problems, mechanical problems (mainly based on a lack of redundant material handling systems), and difficulties in producing a marketable pelletized EQ biosolids product, and it has subsequently been dismantled and scrapped.

There are a few emerging technologies, such as minergy, glassification, or conversion to synfuels, that also result in marketable end products. Minergy and glassification produce a dry material that can be incorporated into construction materials, and conversion to synfuels produces a marketable alternative fuel. However, these technologies are all substantially more energy intensive, come with higher capital costs for the facilities, and entail higher annual operation and maintenance costs than any of the three basic management options. Cost estimates for those technologies are generally in the range of $250 per wet ton and higher. Those technologies are also highly cost dependent on the economy of scale, with larger facilities being significantly more economical on a cost per ton treated basis, so any practical use of them in Vermont in order to be economically feasible would likely necessitate regional facilities and the associated costs of transporting sludge from local WWTFs to the regional facilities. The scale of Vermont's sludge production is also an impediment to implementing most of these advanced technologies in the state. Several municipalities have looked into some of these technologies only to discover that the technology's purveyors would only consider Vermont's largest WWTF (Rutland, at 6.8 MGD design flow, but currently operating at ~60% of design flow) suitable as a pilot scale facility, even if was operating at or near its design parameters.

In 2006, EPA produced a report, "Emerging Technologies for Biosolids Management", which provides an excellent overview of most currently available and emerging technologies, and reaches most of the same conclusions as CSWD's analysis.

That EPA report evaluated approximately 90 different emerging technologies for the treatment of sludge prior to its ultimate use or disposal. Those technologies were grouped into the broad headings of conditioning, thickening, stabilization, dewatering, thermal conversion, drying, and other processes. It must be noted that in all of the technologies evaluated, none result in the complete destruction of sludge and all produce their own type of residual waste that must still be managed via one of the three basic options (land application, landfilling, or incineration),

although several do produce an end product (typically an ash) that is potentially suitable for incorporation into other products (asphalt, concrete, building materials, glass, etc.) rather than landfilling. Even the process of converting sludge to synfuels leaves its own type of sludge which must be appropriately managed. These ash or tar-like end byproducts are not suitable for application to the land (the metals have been concentrated, the protectiveness derived from the original organic content of the sludge destroyed, and there is no longer any nutrient or soil conditioning value), nor are they amenable to incineration (they have already been "incinerated"), so the sole remaining disposal option is use in other products or landfilling.

It must also be recognized that none of the technologies resulting in an end product with the potential to be managed via application to the land provide any significant reductions in the potential suite of contaminants that may be contained in the biosolids, and therefore do little to mitigate the concerns their presence may present related to protection of groundwater and water quality in land application management strategies. While ozonation or filtration through activated carbon media of finished WWTF effluent likely provides the most efficient means of removing unwanted organic compounds prior to discharging the effluent to surface waters, these technologies are generally very limited in their efficiency and come with excessively high operating and maintenance costs when used in an attempt to remove those same pollutants from influent sewage before they are partitioned into the sludge during the biological treatment processes. These limitations mainly derive from all the other "trash" and organic matter that is typically found in sewage influent and its impact on filter media longevity (which itself is very expensive to maintain and replace) or the need to produce ozone in sufficient quantities to reach the target pollutants as well as the ozone reactive trash and other organic material in the influent (an exceedingly expensive proposition in its own right, as ozone requires large amounts of electrical power to generate). For those same reasons, ozonation and activated carbon filtration are highly inefficient, if not unworkable, processes for the removal or destruction of unwanted pollutants in sludge, biosolids, and septage.

Regardless of the limited set of alternative management options currently available for septage and solids management, any consideration of a mandate to manage these materials in any manner other than by application to the land (as either Class B or EQ biosolids) must consider the implications of such an action. Slightly more than 40,00 wet tons of Vermont generated sludge was processed to biosolids standards and ultimately applied to the land in 2017. Although 64% of that total was processed at out-of-state facilities, and the majority likely applied in areas proximate to the facility at which it was treated (absent data, the amount imported back into Vermont is unknown), approximately 116,600 wet tons of biosolids was processed in Vermont and applied to Vermont lands. In addition, approximately 6.7 million gallons of septage was managed by application to Vermont lands and approximately 255,000 gallons of septage and 300 wet tons of sludge was disposed at incineration facilities in 2017. Because most sewage sludge incinerators proximate to Vermont closed in early 2016 rather than upgrading to new federal air pollution control standards for sewage sludge incinerators, approximately 1 million gallons of septage had to be disposed elsewhere from 2016 to 2017.

In October 2015, the CSWD signed a contract for a Biosolids Facility Engineering Feasibility Study with a local engineering firm to develop and evaluate a feasible engineering alternative narrative, process flow schematic, conceptual basis of design, site plan and life cycle cost analysis for a thermophilic-mesophilic anaerobic sludge digestion facility to be located in Chittenden County to produce dewatered EQ biosolids, with combined heat, power and phosphorous harvesting. Phosphorus harvesting, which is seeing increasing use with (primarily) dairy manure, is a technology which is relatively new to biosolids applications, that purports to be capable of removing a significant amount of the phosphorus contained in biosolids; thus creating the potential to make the use of EQ biosolids more attractive as an agricultural nutrient source in areas where soils are already overloaded with phosphorus (much of Vermont), and could potentially produce a high phosphorus fertilizer for marketing in locations where serious shortages of phosphorus exist (most of the world).

## References

Abt Associates. 1992. "Human Health Risk Assessment for the Use and Disposal of Sewage Sludge: Benefits of Regulation". nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=50000RY7.TXT

American Society for Microbiology. 2011. "Land Application of Organic Residuals: Public Health Threat or Environmental Benefit?" http://www.asm.org/index.php/component/content/article?id=7489:biorep8-2011

Andrews, WJ, JR Masoner, and IM Cozzarelli. 2012. "Emerging Contaminants at a Closed and an Operating Landfill in Oklahoma." *Ground Water Monitoring & Remediation* 32(1): 120-130.

Bassil, RJ, II Bashour, FT Sloiman and YA Abou-Jawdoh. 2013. "Antibiotic uptake by plants from manure-amended soils." *Journal of Environmental Science and Health, Part B: Pesticides, Food Contaminants and Agricultural Wastes* 48(7): 570-574. http://dx.doi.org/10.1080/03601234.2013.774898

Beecher, N. 2008. "A Greenhouse Gas Emissions Analysis of Biosolids Management Options for Merrimack, NH." Northeast Biosolids and Residuals Association (NEBRA). April 2008. http://www.nebiosolids.org/uploads/pdf/MerrmckC02AnalysFINALApr08.pdf

Beecher, N. 2012. "Current Biosolids Use, Regulatory Trends, and Public Perception in New England." *Journal of the New England Water Environment Association* 46(3) (Fall 2012): 17-25.

Blair, BD, JP Crago, CJ Hedman and RD Klaper. 2013. "Pharmaceuticals and personal care products found in the Great Lakes above concentrations of environmental concern." *Chemosphere*, 1–8.

Blakley, B. 2016. "Overview of Lead Poisoning" Merck Vererinary Manual. http://www.merckvetmanual.com/toxicology/lead-poisoning/overview-of-lead-poisoning

Boxall, ABA, and P Johnson. 2006. "Uptake of Veterinary Medicines from Soils into Plants." *Journal of Agricultural* (3): 2288–2297. http://pubs.acs.org/doi/abs/10.1021/jf053041t

Boxall, ABA. 2012. "New and Arising Water Pollutants arising From Agriculture." Environment Department, University of York, United Kingdom.https://www.oecd.org/tad/sustainable-agriculture/49848768.pdf

Brooks, JP, SL Maxwell, C Resnging, CP Gerba and IL Pepper. 2007. "Occurrence of antibiotic-resistent bacteria and endotoxin associated with the land application of biosolids." *Canadian Journal of Microbiology* 53: 616-622.

Brooks, JP, MR McLaughlin, CP Gerba and IL Pepper. 2012. "Land Application of Manure and Class B Biosolids: An Occupational and Public Quantitative Microbial Risk Assessment." *Journal of Environmental Quality* 41(6): 2009-2023.

Brown, SL, RL Chaney, J Hallfrish, JA Ryan and WR Beti. 2004. "In situ soil treatments to reduce the phyto- and bioavailability of lead, zinc, and cadmium." *Journal of Environmental Quality* 33: 522–531.

Brown, S, M Sprenger, A Maxemchuk and H Compton. 2005. "Ecosystem Function in Alluvial Tailings after Biosolids and Lime Addition." *Journal of Environmental Quality* 34: 139-148.

Chambers BJ, FA Nicholson, M Aitken, E Cartmell, and C Rowlands. 2003. "Benefits of Biosolids to Soil Quality and Fertility. *Water and Environment Journal* 17(3): 162-167

Calderón-Preciado, D, V Matamoros, and JM Bayona. 2011. "Occurrence and Potential Crop Uptake of Emerging Contaminants and Related Compounds in an Agricultural Irrigation Network." *The Science of the Total Environment* 412-413 (December 15): 14–9. http://www.ncbi.nlm.nih.gov/pubmed/22030249

Canadian Council of Ministers of the Environment. 2009. The Biosolids Emissions of Assessment Model (BEAM): A Method for Determining Greenhouse Gas Emissions from Canadian Biosolids Management Practices. PN 1432. http://www.ccme.ca/assets/pdf/beam_final_report_1432.pdf

Chambers BJ, FA Nicholson, M Aitken, E Cartmell, and C Rowlands. 2003. "Benefits of Biosolids to Soil Quality and Fertility. *Water and Environment Journal* 17(3): 162-167.

Chaney, RL, J Ryan, G O'Connor. 1996. "Organic contaminants in municipal biosolids: Risk assessment, quantitative pathways analysis, and current research priorities." *Science of the Total Environment* 185: 187-216. http://www.researchgate.net/publication/223925289_Organic_contaminants_in_municipal_biosolids_risk_assessment_quantitative_pathways_analysis_and_current_research_priorities

Chaney, RL, JA Ryan, and SL Brown. 1999. "Environmentally acceptable endpoints for soil metals". pp. 111- 155. *In* W.C. Anderson, R.C. Loehr and D. Reible (eds.) Environmental Availability of Chlorinated Organics, Explosives, and Metals in Soils. *American Academy of Environmental Engineering*, Annapolis, MD.

Clark, BO and SR Smith. 2011. Review of 'emerging' organic contaminants in biosolids and assessment of international research priorities for the agricultural use of biosolids. *Environment Internationl* 37: 226-247. http://www.bibra-information.co.uk/site_files/Clarke%20%26%20Smith%202010.pdf

Cortés, JM, E Larsson, and JA Jönsson. 2013. "Study of the Uptake of Non-Steroid Anti-Inflammatory Drugs in Wheat and Soybean after Application of Sewage Sludge as a Fertilizer." *The Science of the Total Environment* 449 (April 1): 385–9. http://www.ncbi.nlm.nih.gov/pubmed/23454699

Dodgen, LK, J Li, D Parker, and JJ Gan. 2013. "Uptake and Accumulation of Four PPCP/EDCs in Two Leafy Vegetables." *Environmental Pollution (Barking, Essex : 1987)* 182C (July 30): 150–156. http://www.ncbi.nlm.nih.gov/pubmed/23911624

Dolliver, H, K Kumar, and S Gupta. 2007. "Sulfamethazine Uptake by Plants from Manure-Amended Soil." *Journal of Environment Quality* 36 (4): 1224–1230. https://www.agronomy.org/publications/jeq/abstracts/36/4/1224

Drury, B, J Scott, EJ Rosi-Marshall, JJ Kelly. 2013. "Triclosan Exposure Increases Triclosan Resistance and Influences Taxonomic Composition of Benthic Bacterial Communities." *Environmental Science & Technology* 47: 8923-8930. http://www.ncbi.nlm.nih.gov/pubmed/23865377

Edwards, M, E Topp, CD Metcalfe, H Li, N Gottschall, P Bolton, W Curnoe, M Payne, A Beck, S Kleywegt, DR Lapen. 2009. "Pharmaceutical and personal care products in tile drainage following surface spreading and injection of dewatered municipal biosolids to an agricultural field" *Science of the Total Environment* 407: 4220-4230.

Eggen, T, TNAsp, K Grave, and V Hormazabal. 2011. "Uptake and Translocation of Metformin, Ciprofloxacin and Narasin in Forage- and Crop Plants." *Chemosphere* 85 (1): 26–33. http://www.ncbi.nlm.nih.gov/pubmed/21757221

Eggen, T, ES Heimstad, AO Stuanes, and HR Norli. 2013. "Uptake and Translocation of Organophosphates and Other Emerging Contaminants in Food and Forage Crops." *Environmental Science and Pollution Research International* 20 (7) (July): 4520–31. http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3695667&tool=pmcentrez&rendertype=abstract

Fries, GF. 1996. "Ingestion of Sludge Applied Organic Chemicals by Animals." *The Science of the Total Environment* 185 (1-3) (June 21): 93–108. http://www.ncbi.nlm.nih.gov/pubmed/8643962

Gottschall, N, E Topp, C Metcalfe, M Edwards, M Payne, S Kleywegt, P Russell, and DR Lapen. 2012. "Pharmaceutical and Personal Care Products in Groundwater, Subsurface Drainage, Soil, and Wheat Grain, Following a High Single Application of Municipal Biosolids to a Field." *Chemosphere* 87 (2): 194–203. http://www.sciencedirect.com/science/article/pii/S0045653511013877

Guerra, P, M. Kim, L. Kinsman, T. Ng, M. Alaee, S.A. Smyth. 2014 "Parameters Affecting the Formation of Perfluoroalkyl Acids During Wastewater Treatment," *Journal of Hazardous Materials* 272 (2014) 148-154. http://www.sciencedirect.com/science/article/pii/S0304389414001927

Hale, RC, MJ La Guardia, E Harvey, D Chen, TM Mainor, DR Luellen, and LS Hundal. 2012. "Polybrominated Diphenyl Ethers in U.S. Sewage Sludges and Biosolids: Temporal and Geographical Trends and Uptake by Corn Following Land Application." *Environmental Science & Technology* 46 (4) (February 21): 2055–63. http://www.ncbi.nlm.nih.gov/pubmed/22295899

Harrison, EZ, SR Oakes, MHysell, and A Hay. 2006. "Organic Chemicals in Sewage Sludges." *The Science of the Total Environment* 367 (2-3) (August 31): 481–97. http://www.ncbi.nlm.nih.gov/pubmed/16750559

Harrison, EZ, SR Oakes. 2002 "Investigation of Alleged Health Incidents Associated With Land Application of Sewage Sludges." *New Solutions* Vol. 12(4) 387-408. http://cwmi.css.cornell.edu/Sludge/Newsolutions.pdf

Hartman WJ Jr. 1975. "An evaluation of land treatment of municipal wastewater and physical siting of facility installations". U.S. Department of the Army, Washington, DC

Heidler, J & RU Halden. 2007. "Mass balance assessment of triclosan removal during conventional sewage treatment." *Chemosphere*, *66*(2), 362–369. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16766013

Herklotz, PA, P Gurung, B Vanden Heuvel, and CA Kinney. 2010. "Uptake of Human Pharmaceuticals by Plants Grown Under Hydroponic Conditions." *Chemosphere* 78 (11): 1416–1421. http://www.ncbi.nlm.nih.gov/pubmed/20096438

Holling, CS, JL Bailey, BVanden Heuvel, and CA Kinney. 2012. "Uptake of Human Pharmaceuticals and Personal Care Products by Cabbage (Brassica Campestris) from Fortified and Biosolids-Amended Soils." *Journal of Environmental Monitoring* 14 (11) (November): 3029–36. http://www.ncbi.nlm.nih.gov/pubmed/23051741

Holzem, RM, Stapleton, HM, and Gunch, CK. 2014. "Determining the Ecological Impacts of Organic Contaminants in Biosolids Using a High-Throughput Colorimetric Denitrification Assay: A Case Study with Antimicrobial Agents". *Environmental Science and Technology* Feb. 4, 2014.

Jjemba, PK. 2002. "The Potential Impact of Veterinary and Human Therapeutic Agents in Manure and Biosolids on Plants Grown on Arable Land: a Review." *Agriculture, Ecosystems & Environment* 93 (1-3): 267–278. http://linkinghub.elsevier.com/retrieve/pii/S0167880901003504

Karnjanapiboonwong, A, DA Chase, JE Cañas, WA Jackson, JD Maul, AN Morse, and TA Anderson. 2011. "Uptake of 17α-Ethynylestradiol and Triclosan in Pinto Bean, Phaseolus Vulgaris." *Ecotoxicology and Environmental Safety* 74 (5) (July): 1336–42. http://www.ncbi.nlm.nih.gov/pubmed/21513980

Kennedy/Jenks Consultants. 2015. "Biosolids Risk Assessment". Prepared for Northwest BiosolidsManagement Association. Text available upon request.

Kinney, CA, ET Furlong, DW Kolpin, MR Burkhardt, SD Zaugg, SL Werner, JP Bossio, and MJ Benotti. 2008. "Bioaccumulation of Pharmaceuticals and Other Anthropogenic Waste Indicators in Earthworms from Agricultural Soil Amended with Biosolid or Swine Manure." *Environmental Science Technology* 42 (6): 1863–1870.

Kinney, CA, ET Furlong, SD Zaugg, MR Burkhard, SL Werner, JD Cahill, and GR Jorgensen. 2006. "Survey of Organic Wastewater Contaminants in Biosolids Destined for Land Application." *Environmental Science Technology* 40 (23): 7207–7215. http://www.ncbi.nlm.nih.gov/pubmed/17180968

Kipper, K, K Herodes, M Lillenberg, L Nei, E Haiba, and SV Litvin. 2010. "Plant Uptake of Some Pharmaceuticals Commonly Present in Sewage Sludge Compost." *2nd International Conference on Chemical Biological and Environmental Engineering (ICBEE 2010)*: 261–264.

Kjeldsen, P, MA Barlaz, AP Rooker, A Baun, A Ledin and TH Christensen. 2002. "Present and Long-Term Composition of MSW Landfill Leachate: A Review. *Critical Reviews in Environmental Technology* 32(4):297-336.

Kolpin, DW, ET Furlong, MT Meyer, EM Thurman, SD Zaugg, LB Barber, HT Buxton. 2002. "Pharmaceuticals, hormones, and other organic wastewater contaminants in US streams, 1999-2000: a national reconnaissance. *Environmental Science Technology*, 36: 1202-1211.

Kumar, K, SC Gupta, SK Baidoo, Y Chander, and CJ Rosen. 2005. "Antibiotic Uptake by Plants from Soil Fertilized with Animal Manure." *Journal of Environmental Quality* 34 (6): 2082–2085. http://www.ncbi.nlm.nih.gov/pubmed/16221828

Langdon, KA, M St J Warne, RJ Smernik, A Shareef, and RS Kookana. 2012. "Field Dissipation of 4-Nonylphenol, 4-t-Octylphenol, Triclosan and Bisphenol A Following Land Application of Biosolids." *Chemosphere* 86 (10) (March): 1050–8. http://www.ncbi.nlm.nih.gov/pubmed/22196087

Lapen, DR, E Topp, CD Metcalfe, H Li, M Edwards, N Gottschall, P Bolton, W Curnoe, M Payne, A Beck, 2008. "Pharmaceutical and personal care products in tile drainage following land application of liquid municipal biosolids". *Science of the Total Environment* 399, 50–65.

Leu, S-Y, L Chan, and MK Stenstrom. 2012. "Toward Long Solids Retention Time of Activated Sludge Processes: Benefits in Energy Saving, Effluent Quality, and Stability." *Water Environment Research* 84 (1): 42–53. http://www.ingentaconnect.com/content/wef/wer/2012/00000084/00000001/art00006

Lorber, M. 2008. "Exposure of Americans to polybrominated diphenyl ethers". *Journal of Exposure Science & Environmental Epidemiology* 18(1): 2-19. http://www.ncbi.nlm.nih.gov/pubmed/17426733

Macherius, A, T Eggen, WG Lorenz, T Reemtsma, U Winkler, and M Moeder. 2012. "Uptake of Galaxolide, Tonalide, and Triclosan by Carrot, Barley, and Meadow Fescue Plants." *Journal of Agricultural and Food Chemistry* 60 (32) (August 15): 7785–91. http://www.ncbi.nlm.nih.gov/pubmed/22813076

Macherius, A, T Eggen, W Lorenz, M Moeder, J Ondruschka, and T Reemtsma. 2012. "Metabolization of the Bacteriostatic Agent Triclosan in Edible Plants and Its Consequences for Plant Uptake Assessment." *Environmental Science Technology* 46: 10797–804.

Masoner, JR Kolpin DW, Furlong ET, Cozzarelli IM, Gray JL, Schwab EA. 2012. "Contaminants of emerging concern in fresh leachate from landfills in the conterminous United States." Environ Sci Process Impacts. 2014;16(10):2335-54.

Moss, LH, E Epstein, T Logan, SD Frank and K Scott. 2002. "Evaluating Risks and Benefits of Soil Amendments Used in Agriculture." Water Environment Research Foundation (WERF) Report: 99-PUM-1RD. ISBN: 9781843396512.

National Research Council (NRC). 1996. *Use of Reclaimed Water and Sludge in Food Crop Production*, Washington DC: National Academy Press. http://www.nap.edu/catalog.php?record_id=5175

National Research Council (NRC). 2002. "Biosolids Applied to Land: Advancing Standards and Practices." Washington, DC: The National Academies Press. http://www.casaweb.org/documents/2014/2002-national-academy-of-science-biosolids_report.pdf

North East Biosolids and Residuals Associateion (NEBRA). 2007. A National Biosolids Regulation, Quality, End Use and Disposal Survey. Final Report. July 20, 2007.

Overcash, M and D Pal. 1979. Design of land treatment systems for industrial wastes. Ann Arbor Sci., Ann Arbor, MI.

Overcash, M, RC Sims, JL Sims, and JKC Nieman. 2005. "Beneficial Reuse and Sustainability: The Fate of Organic Compounds in Land-Applied Waste." *Journal of Environmental Quality* 34 (1): 29–41. http://www.ncbi.nlm.nih.gov/pubmed/15647532

Pannu, MW, GS Toor, GA O'Connor, and PC Wilson. 2012. "Toxicity and Bioaccumulation of Biosolids-Borne Triclosan in Food Crops." *Environmental Toxicology and Chemistry / SETAC* 31 (9) (September): 2130–7. http://www.ncbi.nlm.nih.gov/pubmed/22761010

Pepper, IL, H Zerzghi, JP Brooks, and CP Gerba. 2008. "Sustainability of Land Application of Class B Biosolids." *Journal of Environmental Quality* 37 (5 Suppl): S58–67. http://www.ncbi.nlm.nih.gov/pubmed/18765778

Pepper, IL, JP Brooks, RG Sinclair, PL Gurian, CP Gerba. 2010. Pathogens and Indicators in United States Class B Biosolids: National and Historic Distributions. *Journal of Environmental Quality* 39: 2185-2190.

Phillips, P & A Chalmers. 2009. "Wastewater Effluent, Combined Sewer Overflows, and Other Sources of Organic Compounds to Lake Champlain." *Journal of the American Water Resources Association*, *45*(1), 45–57.

Phillips, PJ, AT Chalmers., JL Gray, DW Kolpin, WT Foreman, & GR Wall. 2012. "Combined Sewer Over flows: An Environmental Source of Hormones and Wastewater Micropollutants." *Environmental Science and Technology* 46: 5336-5343.

Rideout, K, and K Teschke. 2004. "Potential for Increased Human Foodborne Exposure to PCDD/F When Recycling Sewage Sludge on Agricultural Land." *Environmental Health Perspectives* 112 (9) (April 26): 959–969. http://www.ehponline.org/ambra-doi-resolver/10.1289/ehp.6802

Roberts, P., JP Roberts, and DL Jones. 2006. "Behaviour of the Endocrine Disrupting Chemical Nonylphenol in Soil: Assessing the Risk Associated with Spreading Contaminated Waste to Land." *Soil Biology and Biochemistry* 38 (7) (July): 1812–1822. http://linkinghub.elsevier.com/retrieve/pii/S0038071706000599

Roccaro P., Vagliasindi, F. 2014. " Risk Assessment of the Use of Biosolids Containing Emerging Organic Contaminants in Agriculture." *Chemical Engineering Transactions* Vol. 37, p. 817 http://www.aidic.it/cet/14/37/137.pdf

Rossi-Marshall, D, DW Kincaid, HA Bechtold, TV Royer, M Rojas, JJ Kelly. 2013. "Pharmaceuticals suppress algal growth and microbial respiration and alter bacterial communities in stream biofilms." *Ecological Applications* 23(3): 583-593.

Rusin, PA, SL Maxwell, JP Brooks, CP Gerba, IL Pepper. 2003. "Evidence for the absence of *Staphylococcus aureus* in land applied biosolids." *Environmental Science & Technology* 37(18): 4027-30.http://www.ncbi.nlm.nih.gov/pubmed/14524431

Ryan, JA, WR Berti, SL Brown, SW Casteel, RL Chaney, M Doolan, P Grevatt, JG Hallfrisch, M Maddaloni, D Mosby. 2004. "Reducing children's risk to soil lead: summary of a field experiment." *Journal of Environmental Science and Technology* 38(1):18A-24A.

Sabourin, L, A Beck, PW Duenk, S Kleywegt, DR Lapen, H Li, CD Metcalfe, M Payne, and E Topp. 2009. "Runoff of Pharmaceuticals and Personal Care Products Following Application of Dewatered Municipal Biosolids to an Agricultural Field." *Science of the Total Environment* 407: 4596–4604.

Sabourin, L, P Duenk, S Bonte-Gelok, M Payne, DR Lapen, and E Topp. 2012. "Uptake of Pharmaceuticals, Hormones and Parabens into Vegetables Grown in Soil Fertilized with Municipal Biosolids." *The Science of the Total Environment* 431 (August 1): 233–6. http://www.ncbi.nlm.nih.gov/pubmed/22687432

Scandura and Sobsey. 1997. "Viral and bacterial contamination of groundwater from on-site sewage treatment systems". *Water Science & Technology* 35(11-12): 141-146. http://www.sciencedirect.com/science/article/pii/S0273122397002497

Schiffman, SS, JM Walker, P Dalton, TS Lorig, JH Raymer, D Shusterman and CM Williams. 2004. "Potential Health Effects of Odor from Animal Operations, Wastewater Treatment, and Recycling of Byproducts." *Journal of Agromedicine* 9(2): 397-403.

Shambaugh, N. 2016 "Organic Contaminants of Emerging Concern in the Lake Champlain Basin: A Review of Current Knowledge 2016". Lake Champlain Basin Program. http://anr.vermont.gov/sites/anr/files/specialtopics/Act154ChemicalUse/Organic%20Contaminants%20of%20Emerging%20Concern%20in%20the%20Lake%20Champlain%20Basin,%20A%202016%20Review%20of%20Current%20Knowledge.pdf

Snyder, EH, and GA O'Connor. 2013. "Risk Assessment of Land-Applied Biosolids-Borne Triclocarban (TCC)." *The Science of the Total Environment* 442 (January 1): 437–44. http://www.ncbi.nlm.nih.gov/pubmed/23183124

Snyder, ElH, GA O'Connor, and DC McAvoy. 2011. "Toxicity and Bioaccumulation of Biosolids-Borne Triclocarban (TCC) in Terrestrial Organisms." *Chemosphere* 82 (3) (January): 460–7. http://www.ncbi.nlm.nih.gov/pubmed/21035164

Southworth, RM. 1995. "The Part 503 Land Application Pollutant Limits for Arsenic." U.S. Environmental Protection Agency, Washington, DC. http://www.casaweb.org/documents/2011/part-503-land-application-limits-arsenic.pdf

Specter, M. (1992, June 29). Ocean Dumping Is Ending, but Not Problems; New York Can't Ship, Bury or Burn Its Sludge, but No One Wants a Processing Plant. *New York Times*. Retrieved from: http://www.nytimes.com/1992/06/29/nyregion/ocean-dumping-ending-but-not-problems-new-york-can-t-ship-bury-burn-its-sludge.html?pagewanted=all&src=pm

Topp, E., Hendel, J., Lu, Z., Chapman, R. (2006), Biodegradation of caffeine in agricultural soils. Can J. Soil Sci. 86: 533-544

Topp, E., Hendel, J.G., Lapen, D.R., Chapman, R. (2008b) Fate of the non-steroidal anti-inflammatory drug naproxen in agricultural soil receiving liquid municipal biosolids. Environ. Toxicol. Chem. 27: 2005-2010.

Trapp, S, and T Eggen. 2013. "Simulation of the Plant Uptake of Organophosphates and Other Emerging Pollutants for Greenhouse Experiments and Field Conditions." *Environmental Science and Pollution Research International* 20 (6) (June): 4018–29. http://www.ncbi.nlm.nih.gov/pubmed/23212267

U.N. - Human Settlements Programme and Greater Moncton Sewerage Commission. 2008. "Global Atlas of Excretia, Wastewater Sludge, and Biosolids Management: Moving Forward the Sustainable and Welcome Uses of a Global Resource." http://esa.un.org/iys/docs/san_lib_docs/habitat2008.pdf

U.S. Census Bureau, Housing and Household Economic Statistics Division, Last Revised: October 31, 2011. http://www.census.gov/hhes/www/housing/census/historic/sewage.html

U.S. Department of Agriculture (USDA). 2009. 2007 Census of agriculture. AC-07-A-51. Volume 1. USDA, National Agricultural Statistics Service. Geographic Area Series, Washington, DC. http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf

U.S. Environmental Protection Agency (EPA). 1993. Standards for the Use or Disposal of Sewage Sludge Title 40 of the Code of Federal Regulations (CFR) Part 503. http://yosemite.epa.gov/r10/water.nsf/NPDES+Permits/Sewage+S825/$FILE/503-032007.pdf

U.S. Environmental Protection Agency (EPA). 1994. *A Plain English Guide to the EPA Part 503 Biosolids*, Washington, DC: USEPA Office of Wastewater Management. EPA-832-R-93-003 http://water.epa.gov/scitech/wastetech/biosolids/503pe_index.cfm

U.S. Environmental Protection Agency (EPA). 1995. A Guide to the Biosolids Risk Assessments for the EPA Part 503 Rule, Washington, DC: USEPA Office of Wastewater Management. EPA-832-B-93-005. http://water.epa.gov/scitech/wastetech/biosolids/503rule_index.cfm

U.S. Environmental Protection Agency (EPA). 2003. EPA Makes Final Decision on Dioxin in Sewage Sludge used in Land Applications. Press Release, 10/17/2003. http://yosemite.epa.gov/opa/admpress.nsf/b1ab9f485b098972852562e7004dc686/209dab87e1b0a8b785256dc20050c977?OpenDocument

U.S. Environmental Protection Agency (EPA). 2003b. December 24, 2003 letter to Joseph Mendelson, III, Legal Director, Center for Food Safety regarding Petition Seeking an Emergency Moratorium on the Land Application of Sewage Sludge, dated October 7, 2003 from G. Tracy Mehan, III, Assistant Administrator, EPA Office of Water, Washington DC.

U.S. Environmental Protection Agency (EPA). 2009. Occurrence of Contaminants of Emerging Concern in Wastewater From Nine Publically Owned Treatment Works. August 2009. EPA-821-R-09-009.

U.S. Environmental Protection Agency (EPA). 2009b. Targeted National Sewage Sludge Survey Sampling and Analysis Technical Report. January 2009. EPA-822-R-08-016.

U.S. Environmental Protection Agency (EPA). 2010. Treating Contaminants of Emerging Concern -A Literature Review Database. August 2010. EPA-820-R-10-002.

U.S. Environmental Protection Agency (EPA). 2012. Water: Sewage Sludge (Biosolids), Frequently Asked Questions. http://water.epa.gov/polwaste/wastewater/treatment/biosolids/genqa.cfm

U.S. Environmental Protection Agency (EPA). 2013. Literature Review of Contaminants in Livestock and Poultry Manure and Implications for Water Quality. Office of Water (4304T). EPA 820-R-13-002. July 2013. http://water.epa.gov/scitech/cec/upload/Literature-Review-of-Contaminants-in-Livestock-and-Poultry-Manure-and-Implications-for-Water-Quality.pdf

Viau, E, K Bibby, T Paez-Rubio, and J Peccia. 2011. "Toward a Consensus View on the Infectious Risks Associated with Land Application of Sewage Sludge." *Environmental Science & Technology* 45 (13) (July 1): 5459–69. doi:10.1021/es200566f. http://www.ncbi.nlm.nih.gov/pubmed/21644497

Vermont Public Interest Research Group (VPIRG). June 1999. "On the Ground" http://www.vpirg.org/download/1999%20June%20Toxic%20Sludge%20report.pdf

Water Environment Federation (WEF). 2004. History of Biosolids. Fact Sheet. http://www.wef.org/Biosolids/page.aspx?id=7514&ekmensel=c57dfa7b_123_0_7514_2

Wild, SR, SJ Harrad, and KC Jones. 1994. "The Influence of Sewage Sludge Applications to Agricultural Land on Human Exposure to Polychlorinated Dibenzo-p-Dioxins (PCDDs) and -Furans (PCDFs)." *Environmental Pollution (Barking, Essex : 1987)* 83 (3) (January): 357–69. http://www.ncbi.nlm.nih.gov/pubmed/15091742

Wong, K, T Harrigan, and I Xagoraraki. 2012. "Leaching and Ponding of Viral Contaminants Following Land Application of Biosolids on Sandy-Loam Soil." *Journal of Environmental Management* 112 (December 15): 79–86. http://www.ncbi.nlm.nih.gov/pubmed/22885066

Wu, C, AL Spongberg, JD Witter, MFang, and KP Czajkowski. 2010. "Uptake of Pharmaceutical and Personal Care Products by Soybean Plants from Soils Applied with Biosolids and Irrigated with Contaminated Water." *Environmental Science Technology* 44 (16): 6157–6161. http://www.ncbi.nlm.nih.gov/pubmed/20704212

Wu, C, AL Spongberg, JD Witter, and BB Maruthi Sridhar. 2012. "Transfer of Wastewater Associated Pharmaceuticals and Personal Care Products to Crop Plants from Biosolids Treated Soil." *Ecotoxicology and Environmental Safety* 85 (November): 104–9. http://www.ncbi.nlm.nih.gov/pubmed/22921256

Yager, TJB, ET Furlong, DW Kolpin, CA Kinney, SD Zaugg, MR Burkhardt. 2014. "Dissipation of Contaminants of Emerging Concern in Biosolids Applied to Nonirrigated Farmland in Eastern Colorado". *Journal of the American Water Resource Association* 50(2): 343-357.

Yang, Y-Y, JL Gray, ET Furlong, JG Davis, RC Revello, and T Borch. 2012. "Steroid Hormone Runoff from Agricultural Test Plots Applied with Municipal Biosolids." *Environmental Science & Technology* 46 (5) (March 6): 2746–54. http://www.ncbi.nlm.nih.gov/pubmed/22283735

Yang, J., Gao, D., Chen, T. et al. 2015. J. Cent. South Univ. 22: 3788. doi:10.1007/s11771-015-2923-x. http://link.springer.com/article/10.1007/s11771-015-2923-x

## APPENDIX 1: Description of Highly Exposed Individuals (HEIs)

The 1989 proposed Part 503 rule considered the exposed individual to be a "most exposed individual" (MEI). EPA changed the exposed individual from the MEI to the HEI so that the final rule would be consistent with a statement in the rule's legislative history that calls for protecting individuals and populations that are "highly exposed to reasonably anticipated adverse conditions." In developing Subpart B of the rule, EPA used different HEIs in evaluating each pathway of potential exposure from the toxic effects of pollutants in land-applied sewage sludge.

For agricultural settings for Pathway 1, which is designed to protect consumers who eat produce grown in sewage sludge-amended soil, the HEI is assumed to live in a region where a relatively high percentage of the available cropland receives sludge applications. Although all vegetables in the diet could be presumed to be affected, this assumption was considered to be too severe a worst case. Instead it was assumed that the HEI ingests a mix of crops from land on which sludge was applied as well as from land on which sludge was not applied.

For nonagricultural settings for Pathway 1, the HEI is a person who regularly harvests edible wild plants (i.e., berries and mushrooms) from forests or range lands that have been amended with sewage sludge. This food is preserved by drying, freezing, or canning and is, hence, available for consumption throughout the year. It is also assumed that an individual could continue with this practice for a lifetime, estimated as 70 years.

Pathway 2 evaluates the effects to home gardeners from consuming crops grown in residential home gardens that have been amended with sewage sludge. The major difference between Pathways 1 and 2 is the fraction of food assumed to be grown on sewage sludge-amended soil. The HEI for Pathway 2 is the home gardener who produces and consumes potatoes, leafy vegetables, fresh legumes, root vegetables, garden fruits (e.g., tomatoes, eggplants), sweet corn, and grains. (These are also consumed but not produced by the HEI in Pathway 1.) Unlike Pathway 1, peanuts and dried legumes are not included, because the HEI in Pathway 2 is unlikely to grow them in residential settings.

The HEI for Pathway 3, which assesses the hazard to a child from ingesting undiluted sewage sludge, is a child ingesting sewage sludge from storage piles or from the soil surface. For the residential setting, this HEI is assumed to be a child between the ages of 1 and 6. In the

5-4

nonagricultural setting, it is unlikely that a child younger than 4 years old would be unattended for a long enough time to ingest the sludge. The HEI for the nonagricultural setting is therefore assumed to be exposed for 2 years between the ages of 4 and 6.

The HEI for Pathway 4 is an individual consuming foraging animals that consumed feed crops or vegetation grown on sewage sludge-amended soils. The HEI is assumed to consume daily quantities of the various animal tissue foods and to be exposed to background levels of pollutants from sources other than sludge. For the agricultural setting, the affected animal foods evaluated were beef, beef liver, lamb, pork, poultry, dairy, and eggs.

In the nonagricultural setting, the HEI for this pathway is assumed to be a hunter who preserves meat (including liver) for consumption through the year. The animals hunted in the forest and eaten are assumed to be deer and elk. Although other animals could be hunted and consumed, the Agency evaluated only these large mammals because their greater size makes them capable of having a more significant impact on the total human diet.

Pathway 5 involves the application of sewage sludge to the land, the direct ingestion of this sewage sludge by animals, and, finally, the consumption of contaminated animal tissue by humans. The HEI is assumed to consume various animal tissue foods and is also assumed to be exposed to a background intake of pollutants.

Pathway 6 evaluates animals that ingest plants grown on sewage sludge-amended soil. The HEI for both agricultural and nonagricultural uses is a highly sensitive herbivore that consumes plants grown on sewage sludge-amended soil. Background intake is taken into account by considering background concentration of pollutants in forage crops. In a forest application site there are two HEIs: domestic animals that graze, and small herbivorous mammals such as deer mice that live their entire lives in a sewage sludge-amended area feeding on seeds and small plants close to the layer of soil amended with sewage sludge. In the agricultural setting, the HEI is a larger grazing mammal, such as a sheep.

The HEI for Pathway 7 is an herbivorous animal that incidentally consumes sewage sludge adhering to forage crops and/or sewage sludge on the soil surface. Background intake is

considered to be from ingesting soil having background levels of pollutant. Since forest animals more typically browse rather than graze, the HEI for agricultural settings is used as a reasonable worst-case surrogate for the nonagricultural HEI.

Pathway 8, the plant phytotoxicity pathway, assumes for its HEI a plant sensitive to the pollutants in sewage sludge. The literature search carried out for this pathway included information on nonagronomic species, which were shown to be no more sensitive than agronomic species. Therefore, the limits set for agricultural species also protect wild species found in nonagricultural settings.

The HEI for Pathway 9 is a soil organism sensitive to the pollutants in sewage sludge—an earthworm. Since all soil organisms are wild species, the same HEI is used for the agricultural as well as the nonagricultural settings.

The HEI for Pathway 10, the soil organism-predator pathway, is wildlife—the shrew mole--that consumes soil organisms that have been feeding on sewage sludge-amended soil. As with Pathway 9, the same HEI is used for both the nonagricultural and agricultural pathways.

Pathway 11, which protects humans from the effects of airborne dusts containing sewage sludge, has as its HEI a tractor driver tilling a field. This pathway evaluates the impact of particles that have been resuspended by the driver's tilling dewatered sewage sludge into the soil. This pathway applies only to the agricultural setting, since tractors are not usually found in nonagricultural settings such as forests.

Pathway 12, the soil erosion pathway, has as an HEI a human who consumes 2 liters/day of drinking water from surface water contaminated by soil eroded from a site where sewage sludge has been land-applied and who ingests 0.04 kg/day of fish from surface waters contaminated by sewage sludge pollutants. The HEI is the same for agricultural and nonagricultural practices.

The HEI for Pathway 13 is a human who inhales the vapors of any volatile pollutants that may be in the sewage sludge when it is applied to the land. The wind direction is assumed never

to change, so that the HEI is assumed to live at the downwind edge of the site. The same plume model was used for both the agricultural and nonagricultural settings.

The HEI for Pathway 14 for agricultural and nonagricultural settings is an individual who obtains his or her drinking water from ground water located directly below a field to which sewage sludge has been applied.

#### *5.1.2.2 Decisions Related to Calculating the Human Dose*

##### 5.1.2.2.1 Oral Reference Dose (RfD)

An oral reference dose (RfD) of a pollutant is a threshold below which effects adverse to human health are unlikely to occur. Where the Agency has not published human health criteria for a noncarcinogenic pollutant, the RfD listed in EPA's computerized Integrated Risk Information System (IRIS) was used (U.S. EPA, 1992h). The RfDs listed in IRIS are based on a process within the Agency that includes review of the latest scientific information.

##### 5.1.2.2.2 Recommended Dietary Allowances (RDAs)

RDAs are defined as the levels of intake of essential nutrients that, on the basis of scientific knowledge, are judged by the Food and Nutrition Board to be adequate to meet the known nutrient needs of practically all healthy persons (NAS, 1989). Although RfDs were used to determine the concentrations of inorganic pollutants that are protective of human health, the RDA was used in two cases: zinc and copper. Since there is at present no Agency-approved RfD for copper, the RDA was used as a reasonably protective dose. In the case of zinc, the Agency has established an RfD, but that value is insufficient to meet the daily nutritional requirements of the exposed population. The Agency therefore chose to use the higher RDA value.

# APPENDIX 2: Landfill Leachate Composition

NOTE: These analyses were selected at random and may or may not be representative of typical.

**Table A-1: Xenobiotic Organic Compounds in Landfill Leachates (Kjeldsen et al. 2002)**

| Compound | Concentration Range (µg/L) |
|---|---|
| **Aromatic hydrocarbons** | |
| benzene | 0.2 - 1630 |
| toluene | 1 - 12300 |
| xylene | 0.8 - 3500 |
| ehtylbenzene | 0.223 |
| trimethylbenzenes | 0.3 - 250 |
| n-propylbenzene | 0.3 - 16 |
| t-butylbenzene | 2.1 - 21 |
| o-ethyltoluene | 0.5 - 46 |
| m-ethyltoluene | 0.3 - 21 |
| p-ethyltoluene | 0.2 - 10 |
| naphthalene | 0.1 - 260 |
| **Halogenated hydrocarbons** | |
| chlorobenzene | 0.1 - 110 |
| 1,2-dichlorobenzene | 0.1 - 32 |
| 1,3-dichlorobenzene | 5.4 - 19 |
| 1,4-dichlorobenzene | 0.1 - 26 |
| 1,2,3-trichlorobenzene | BQL |
| 1,2,4-trichlorobenzene | 4.3 |
| hexachlorobenzene | 0.025 - 10 |
| 1,1-dichloroethane | 0.6 - 46 |
| 1,2-dichloroethane | <6 |
| 1,1,1-trichloroethane | 0.1 - 3810 |
| 1,1,2-trichloroethane | 2.5 - 16 |
| 1,1,2,2-tetrachloroethane | BQL |
| trans-1,2-dichloroethylene | 1.6 - 6582 |
| cis-1,2-dichloroethylene | 1.4 - 470 |
| trichloroethylene | 0.5 - 750 |
| tetrachloroethylene | 0.1 - 250 |
| dichloromethane | 1 - 827 |
| trichloromethane | 1 - 70 |
| carbontetrachloride | 4 - 9 |
| **Phenols** | |
| phenol | 0.6 - 1200 |
| ethylphenols | <300 |
| cresols | 1 - 2,100 |
| bisphenol A | 200 - 400 |
| 3,5-dimethylphenol | 0.7 - 27.3 |
| 2,5-dimethylphenol | 0.4 - 4.5 |
| 2,4-dimethyphenol | 0.1 - 12.5 |
| 3,4-dimethylphenol | 0.03 - 10.4 |
| 2,6-dimethylphenol | 0.3 - 1.9 |
| 2-methoxyphenol | BQL |

**Table A-1 (Continued):**

| | |
|---|---|
| 2,3-dichlorophenol | 0.03 - 1.6 |
| 4-chlorophenol | 0.2 - 1.3 |
| 4-chloro-m-cresol | 1.2 - 10.2 |
| 3,5-dichlorophenol | 0.08 - 0.63 |
| 2,3,4,6-tetrachlorophenol | 0.079 - 3 |
| **Alkylphenols** | |
| nonylphenol | 6.3 - 7 |
| nonylphenol monocarboxylate | 0.5 - 3 |
| **Pesticides** | |
| Ametryn | 0.12 |
| AMPA | 3.8 - 4.3 |
| Atrazine | 0.16 |
| Bentazon | 0.3 - 4 |
| Chloridazon | 1.6 |
| Chlorpropham | 26 |
| Dichlobenil | 0.1 - 0.3 |
| Fenpropimor | 0.1 |
| Glyphosphate | 1.7 - 27 |
| Hexazinon | 1.3 |
| Hydroxyatrizine | 0.7 - 1.7 |
| Hydroxysimazin | 0.6 - 1.7 |
| Isoproturon | 1.2 |
| Lindane | 0.025 - 0.95 |
| Mecoprop | 0.38 - 150 |
| MCPA | 0.2 - 9.1 |
| Propaxuron | 2.6 |
| Simazine | 2.3 |
| Tridimefon | 2.1 |
| 4-CPP | 15 - 19 |
| 2,4-D | 1.0 - 5 |
| 2,4,5-T | BQL |
| 2,4-DP | 0.3 - 5.2 |
| 2,6-DCPP | 0.7 - 1.3 |
| **Phthalates** | |
| monomethyl phthalate | 1 |
| dimethyl phthalate | 0.1 - 7.7 |
| diethyl phthalate | 0.1 - 660 |
| methyl-ethyl phthalate | 20 - 340 |
| mono-(2-ethylhexyl) phthalate | 4 - 14 |
| di-(2-ethylhexyl) phthalate | 0.6 - 236 |
| monobutyl phthalate | 4 - 16 |
| di-n-butyl phthalate | 0.1 - 70 |
| di-isobutyl phthalate | 3 - 6 |
| mono-benzyl phthalate | 6 - 16 |
| butylbenzyl phthalate | 0.8 - 8 |
| dioctyl phthalate | 1 - 6 |
| phthalic acid | 2 - 14000 |

**Table A-1 (Continued):**

| | |
|---|---|
| **Aromatic sulfonates** | |
| naphthalene-1-sulfonate | 506 - 616 |
| naphthalene-2-sulfonate | 1143 - 1188 |
| naphthalene-1,5-disulfonate | 2.5 - 51 |
| naphthalene-1,6-disulfonate | 366 - 397 |
| naphthalene-2,7-disulfonate | 129-145 |
| 2-aminonapthalene-4,8-disulfonate | 73-109 |
| p-toluenesulfonate | 704-1,084 |
| **Phosphonates** | |
| tri-n-butylphosphate | 1.2 - 360 |
| triethylphosphate | 15 |
| **Miscellaneous** | |
| acetone | 6 - 4,400 |
| 2(3H)-benzothiazolone | 10 - 50 |
| camphor | 20.6 - 255.2 |
| cumen | 0.3 - 7.4 |
| fenchone | 7.3 - 83 |
| tetrahydrofuran | 9 - 430 |
| indane | 0.2 - 20 |
| methylethylketone | 110 - 6600 |
| methyl-isobutylketone | 1.1 - 176 |
| dimethoxymethane | 1.1 |
| MTBE | 0.8 - 35 |
| styrene | 0.5 - 1.6 |

BQL = detected below quantification limit

**Table A-2: Concentration of Selected Contaminants in Leachate from a Vermont Landfill (National Landfill Leachate Study, Masoner, et al, USGS, June 2012)**

| Compound | Concentration (µg/L) |
|---|---|
| 10-hydroxy-amitriptyline | 0.86 |
| 19-norethindrone | 0.68 |
| abacavir | BDL |
| acetaminophen | 59.12 |
| aciclovir | 13.27 |
| albuterol | 0.12 |
| alprazolam | BDL |
| amitriptyline | BDL |
| amphetamine | 6.26 |
| antipyrene | 1.98 |
| atenolol | 4.57 |
| atrazine | 1.08 |
| benzotriazole methyl-1H | 11.77 |
| benztropine | BDL |
| betamethasone | BDL |
| bupropion | BDL |
| caffeine | 2.74 |
| carbamazepine | 2.18 |
| carisoprodol | 2.94 |
| chlorpheniramine | 0.09 |
| cimetidine | 2.92 |
| cis-diltiazem | BDL |
| citalopram | BDL |
| clonidine | BDL |
| cocaine | BDL |
| codeine | 0.28 |
| cotinine | 43.32 |
| dehydronifedipine | 1.30 |
| delta9tetrahydrocannabinol | BDL |
| desvenlafaxine | 2.61 |
| dextromethorphan | 0.08 |
| diazepam | BDL |
| diphenhydramine | 0.08 |
| duloxetine | BDL |
| erythromycin | 0.09 |
| esomeprazole | BDL |
| ezetimibe | BDL |
| fadrozole | 0.38 |
| famotidine | BDL |
| fenofibrate | BDL |
| fexofenadine | 0.48 |
| fluconazole | 2.49 |
| fluoxetine | BDL |
| fluticasone | BDL |
| fluvoxamine | 0.08 |
| glipizide | BDL |
| glyburide | BDL |
| hydrocodone | BDL |
| hydrocodone-D3 | 0.08 |

**Table A-2 (Continued):**

| | |
|---|---|
| hydrocortisone | BDL |
| hydroxyzine | BDL |
| iminostilbene | BDL |
| ketoconazole | BDL |
| lamivudine | 0.47 |
| lidocaine | 128.63 |
| loperamide | BDL |
| loratadine | 0.08 |
| lorazepam | 25.68 |
| meprobamate | 1.12 |
| metaxalone | 0.76 |
| metformin | 0.91 |
| methadone | BDL |
| methocarbamol | 2.35 |
| methotrexate | BDL |
| metoprolol | 1.31 |
| morphine | 0.38 |
| nadolol | 1.15 |
| N-desmethyldiltiazem | 0.26 |
| nevirapine | BDL |
| nicotine | 194.45 |
| nizatidine | BDL |
| nordiazepam | BDL |
| norfluoxetine | BDL |
| norfluoxetine-D6 | 0.09 |
| norverapamil | BDL |
| orlistat | BDL |
| oseltamivir | 0.17 |
| oxazepam | 3.59 |
| oxycodone | BDL |
| paraxanthine | 1.59 |
| paroxetine | BDL |
| penciclovir | 1.54 |
| pentoxyfylline | 1.03 |
| phenazopyridine | BDL |
| phendimetrazine | 0.48 |
| phenytoin | 5.14 |
| piperonylbutoxide | 0.09 |
| prednisolone | 23.02 |
| prednisone | BDL |
| promethazine | BDL |
| propanolol | BDL |
| propoxyphene | BDL |
| pseudoephederine | 40.86 |
| quinine | BDL |
| rac-cis-N-desmethylsertraline | BDL |
| raloxifene | 25.59 |
| ranitidine | 0.34 |
| sertraline | BDL |
| sitagliptin | BDL |
| sulfadimethoxine | 85.53 |

**Table A-2 (Continued):**

| | |
|---|---|
| sulfamethizole | BDL |
| sulfamethoxazole | BDL |
| tamoxifen | BDL |
| temazepam | BDL |
| theophylline | 1.71 |
| thiabendazole | 1.62 |
| tiotropium | BDL |
| tramadol | 1.75 |
| triamterene | 0.07 |
| trimethoprim | BDL |
| valacyclovir | 0.48 |
| venlafaxine | 1.72 |
| verapamil | BDL |
| warfarin | 0.12 |

BDL = below detection limit

## Table A-3: Concentration of Selected Parameters in Leachate from a Vermont Landfill (DEC Wastewater Management Program Compliance Files, 2014)



**Laboratory Report** DATE REPORTED: 02/26/2014

CLIENT: [redacted]
PROJECT:

WORK ORDER: **1402-02249**
DATE RECEIVED: 02/06/2014

001 Site: Combined AST Date Sampled: 2/6/14 Time: 9:05

| Parameter | Result | Units | Method | Analysis Date/Time | Lab/Tech | NELAC | Qual. |
|---|---|---|---|---|---|---|---|
| BOD-5day | 2,100 | mg/L | SM20 5210B | 2/6/14 16:06 | W JSS | A | |
| Chloride | 1,700 | mg/L | EPA 300.0 | 2/7/14 | W CM | A | |
| COD | 4900 | mg/L | Hach 8000 | 2/21/14 | N JGM | A | |
| TKN | 990 | mg/L | EPA 351.2 | 2/18/14 | N CAL | A | |
| Arsenic, Total | 0.41 | mg/L | EPA 200.7 | 2/13/14 | W RGT | N | |
| Cadmium, Total | < 0.008 | mg/L | EPA 200.7 | 2/13/14 | W RGT | A | |
| Chromium, Total | 0.23 | mg/L | EPA 200.7 | 2/13/14 | W RGT | A | |
| Copper, Total | < 0.080 | mg/L | EPA 200.7 | 2/13/14 | W RGT | A | |
| Lead, Total | < 0.080 | mg/L | EPA 200.7 | 2/13/14 | W RGT | N | |
| Mercury, Total | < 0.0002 | mg/L | EPA 245.1 | 2/11/14 | W CM | A | |
| Molybdenum, Total | < 0.080 | mg/L | EPA 200.7 | 2/13/14 | W RGT | A | |
| Nickel, Total | 0.42 | mg/L | EPA 200.7 | 2/13/14 | W RGT | A | |
| Selenium, Total | < 0.004 | mg/L | SM20 3113B | 2/18/14 | W AWM | A | |
| Sodium, Total | 1280 | mg/L | EPA 200.7 | 2/13/14 | W RGT | A | |
| Zinc, Total | 1.3 | mg/L | EPA 200.7 | 2/13/14 | W RGT | A | |
| Volatile Organic Compounds | | | | | | | |
| Dichlorodifluoromethane | < 100 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Chloromethane | < 60.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Vinyl chloride | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Bromomethane | < 100 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Chloroethane | < 100 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Trichlorofluoromethane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Diethyl ether | < 100 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| 1,1-Dichloroethene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Acetone | 4,870 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Carbon disulfide | < 100 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Methylene chloride | < 100 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| t-Butanol | 1,700 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | QA- |
| Methyl-t-butyl ether (MTBE) | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| trans-1,2-Dichloroethene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Di-isopropyl ether (DIPE) | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| 1,1-Dichloroethane | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Ethyl-t-butyl ether (ETBE) | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| 2-Butanone | 5,760 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 2,2-Dichloropropane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| cis-1,2-Dichloroethene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Bromochloromethane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Chloroform | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Tetrahydrofuran | 2,620 | ug/L | EPA 8260C | 2/18/14 | W MHM | U | |
| 1,1,1-Trichloroethane | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Carbon tetrachloride | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,1-Dichloropropene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Benzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| t-Amylmethyl ether (TAME) | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| 1,2-Dichloroethane | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Trichloroethene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |

ENDYNE Inc.
www.endynelabs.com

**Table A-3 (continued):**



**Laboratory Report** DATE REPORTED: 02/26/2014

CLIENT: [redacted]
PROJECT:

WORK ORDER: **1402-02249**
DATE RECEIVED: 02/06/2014

001 Site: Combined AST Date Sampled: 2/6/14 Time: 9:05

| Parameter | Result | Units | Method | Analysis Date/Time | Lab/Tech | NELAC | Qual. |
|---|---|---|---|---|---|---|---|
| 1,2-Dichloropropane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Dibromomethane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Bromodichloromethane | < 10.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| cis-1,3-Dichloropropene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 4-Methyl-2-pentanone (MIBK) | < 200 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Toluene | 25.4 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| trans-1,3-Dichloropropene | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,1,2-Trichloroethane | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Tetrachloroethene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,3-Dichloropropane | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| 2-Hexanone | < 200 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Dibromochloromethane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,2-Dibromoethane | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Chlorobenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Ethylbenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,1,1,2-Tetrachloroethane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Xylenes, Total | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Styrene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Bromoform | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Isopropylbenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,1,2,2-Tetrachloroethane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| Bromobenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| n-Propylbenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,2,3-Trichloropropane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| 2-Chlorotoluene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| 1,3,5-Trimethylbenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 4-Chlorotoluene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| t-Butylbenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,2,4-Trimethylbenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| s-Butylbenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| 4-Isopropyltoluene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,3-Dichlorobenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,4-Dichlorobenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| n-Butylbenzene | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,2-Dichlorobenzene | < 20.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,2-Dibromo-3-Chloropropane | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,2,4-Trichlorobenzene | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,3,5-Trichlorobenzene | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Hexachlorobutadiene | < 10.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Naphthalene | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | A | |
| 1,2,3-Trichlorobenzene | < 40.0 | ug/L | EPA 8260C | 2/18/14 | W MHM | N | |
| Surr. 1 (Dibromofluoromethane) | 96 | % | EPA 8260C | 2/18/14 | W MHM | N | |
| Surr. 3 (4-Bromofluorobenzene) | 101 | % | EPA 8260C | 2/18/14 | W MHM | N | |
| Surr. 2 (Toluene d8) | 99 | % | EPA 8260C | 2/18/14 | W MHM | N | |
| Unidentified Peaks | 7 | | EPA 8260C | 2/18/14 | W MHM | U | |
| EPA 8270C Semi-VOA | | | | | | | |

ENDYNE Inc.
www.endynelabs.com

**Table A-3 (continued):**



**Laboratory Report** DATE REPORTED: 02/26/2014

CLIENT: [redacted]
PROJECT:

WORK ORDER: **1402-02249**
DATE RECEIVED: 02/06/2014

001 Site: Combined AST Date Sampled: 2/6/14 Time: 9:05

| Parameter | Result | Units | Method | Analysis Date/Time | Lab/Tech | NELAC | Qual. |
|---|---|---|---|---|---|---|---|
| Extraction EPA 3510C | Extracted | | EPA 3510C | 2/12/14 | W FAA | A | |
| N-Nitrosodimethylamine | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Pyridine | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Aniline | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Bis(2-chloroethyl)ether | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 1,2-Dichlorobenzene | < 40.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 1,3-Dichlorobenzene | < 40.0 | ug/L | EPA 8270d | 2/21/14 | W EEP | A | |
| 1,4-Dichlorobenzene | < 40.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Benzyl alcohol | < 400 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Bis(2-chloroisopropyl)ether | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| N-Nitrosodi-n-propylamine | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Hexachloroethane | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Nitrobenzene | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| N-Nitrosopiperidine | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Isophorone | < 40.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Bis(2-chloroethoxy)methane | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 1,2,4-Trichlorobenzene | < 40.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Naphthalene | 46.4 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 4-Chloroaniline | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Hexachlorobutadiene | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| N-Nitrosodi-n-butylamine | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| 2-Methylnaphthalene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 1-Methylnaphthalene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | U | |
| Hexachlorocyclopentadiene | < 400 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2-Chloronaphthalene | < 40.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 1-Chloronaphthalene | < 40.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| 2-Nitroaniline | < 400 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Dimethyl phthalate | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2,6-Dinitrotoluene | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Acenaphthylene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 3-Nitroaniline | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Acenaphthene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Dibenzofuran | < 40.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| 2,4-Dinitrotoluene | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 1-Naphthylamine | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| 2-Naphthylamine | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Fluorene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Diethyl phthalate | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 4-Chlorophenyl phenyl ether | < 40.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 4-Nitroaniline | < 400 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| N-Nitrosodiphenylamine | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Azobenzene | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | U | |
| 4-Bromophenyl phenyl ether | < 40.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Hexachlorobenzene | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Phenanthrene | 22.6 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Anthracene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |

ENDYNE Inc.
www.endynelabs.com

**Table A-3 (continued):**



**Laboratory Report** DATE REPORTED: 02/26/2014

CLIENT: [redacted]
PROJECT:

WORK ORDER: **1402-02249**
DATE RECEIVED: 02/06/2014

001 Site: Combined AST — Date Sampled: 2/6/14 Time: 9:05

| Parameter | Result | Units | Method | Analysis Date/Time | Lab/Tech | NELAC | Qual. |
|---|---|---|---|---|---|---|---|
| Carbazole | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Di-n-butylphthalate | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Fluoranthene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Benzidine | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Pyrene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Butyl benzyl phthalate | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Benzo(a)anthracene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Chrysene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 3,3'-Dichlorobenzidine | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Bis(2-ethylhexyl)phthalate | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Di-n-octylphthalate | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| Benzo(b)fluoranthene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Benzo(k)fluoranthene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Benzo(a)pyrene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Indeno(1,2,3-cd)pyrene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Dibenzo(a,h)anthracene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Benzo(g,h,i)perylene | < 20.0 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Phenol | 182 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2-Chlorophenol | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2-Methylphenol (o-cresol) | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 3&4-Methylphenol (m&p-cresol) | 2,420 | ug/L | EPA 8270D | 2/25/14 | W EEP | A | |
| Cresols, Total | 2,420 | ug/L | EPA 8270D | 2/25/14 | W EEP | A | |
| 2-Nitrophenol | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2,4-Dimethylphenol | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2,4-Dichlorophenol | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2,6-Dichlorophenol | < 100 | ug/L | EPA 8270D | 2/21/14 | W EEP | N | |
| 4-Chloro-3-methylphenol | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2,4,5-Trichlorophenol | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2,4,6-Trichlorophenol | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 2,4-Dinitrophenol | < 400 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 4-Nitrophenol | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| 4,6-Dinitro-2-methylphenol | < 400 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| Pentachlorophenol | < 200 | ug/L | EPA 8270D | 2/21/14 | W EEP | A | |
| BaP Toxic Equiv. Quotient | < 46.2 | ug/L | EPA 8270D | 2/21/14 | W EEP | U | |
| B/N Surr.1 Nitrobenzene-d5 | 75 | % | EPA 8270D | 2/21/14 | W EEP | N | |
| B/N Surr.2 2-Fluorobiphenyl | 81 | % | EPA 8270D | 2/21/14 | W EEP | N | |
| B/N Surr.3 Terphenyl-d14 | 95 | % | EPA 8270D | 2/21/14 | W EEP | N | |
| Acid Surr.1 2-Fluorophenol | 40 | % | EPA 8270D | 2/21/14 | W EEP | N | |
| Acid Surr.2 Phenol-d8 | 29 | % | EPA 8270D | 2/21/14 | W EEP | N | |
| Acid Surr.3 Tribromophenol | 109 | % | EPA 8270D | 2/21/14 | W EEP | N | |
| Unidentified Peaks | > 10 | | EPA 8270D | 2/21/14 | W EEP | U | |

002 Site: Trip Blank — Date Sampled: 2/3/14 Time: 11:05

| Parameter | Result | Units | Method | Analysis Date/Time | Lab/Tech | NELAC | Qual. |
|---|---|---|---|---|---|---|---|
| Volatile Organic Compounds | | | | | | | |

ENDYNE Inc.
www.endynelabs.com

**Table A-4: Concentration (µg/L) of Emerging Contaminants by Leachate Age (Andrews et al. 2012).**

| Compound | >25 Year Burial | 3-16 Year Burial | <5 Year Burial |
|---|---|---|---|
| 3-methyl-1h-indole | 0.242 | 0.12* | <0.04 |
| 3-beta-coprostanol | <2 | 10.41* | 13.41* |
| cholesterol | <2 | 9.42* | 15.7* |
| beta-sistosterol | <2 | 17.7* | 35.8* |
| 4-t-octylphenol | 1.24* | 0.486* | 0.463* |
| acetophenone | <0.649 | 0.516* | 0.906* |
| benzophenone | <0.216 | 0.807* | 1.07* |
| camphor | 114* | 1.55* | 98.8* |
| d-limonene | 0.245* | 0.302* | <1.75 |
| fluoranthene | <0.04 | 0.273* | <0.04 |
| isoborneol | 0.903 | < 1.13 | <5.26 |
| cumene | 0.945* | 3.48* | 2.06* |
| p-cresol | 51.2* | 35.2* | <0.18 |
| tri(2-butoxyethyl) phosphate | 2.43* | 1.34* | 2.54* |
| tri(dichloroisopropyl) phosphate | 0.195 | <0.12 | <0.1 |
| tributyl phosphate | 2.25* | 2.04* | 1.83* |
| triphenyl phosphate | 0.249 | <0.12 | <0.12 |
| 1-methylnapthalene | 1.59 | 1.45* | 0.728* |
| 2,6-dimethylnapthalene | 0.572 | 0.426* | <0.12 |
| 2-methylnapthalene | 2.25 | 1.9* | 1.02* |
| anthracene | 0.271 | 0.286* | <0.04 |
| naphthalene | 9.53 | 9.91* | 9.07* |
| phenanthrene | 0.215 | 0.338* | <0.04 |
| pyrene | <0.04 | 0.174* | <0.04 |
| 1,4-dichlorobenzene | 2.11* | 4.41* | 24* |
| anthraquinone | 0.26 | 0.271* | 0.702* |
| carbaryl | 0.942* | <0.61 | <0.726 |
| n,n-dimethyl-meta-toluamide (DEET) | 52.6* | 43.7* | 52.8* |

* = estimated concentration, detected below quantification limit

# APPENDIX 3: 2017 Biosolids Management Statistics

**Table A-5: Vermont Biosolids Management Statistics for 2017**

| Management Option | In-State (wet tons)[1] | Out-of-State (wet tons)[1] | Total (wet tons)[1] | Percent of Total | Percent Managed |
|---|---|---|---|---|---|
| **Beneficial Uses:** | | | | | |
| Land Application | 4,459 | 0 | 4,459 | 5.4% | |
| EQ Biosolids | 13,033 | 30,519 | 43,552 | 52.5% | |
| Subtotal | 17,492 | 30,519 | 48,011 | | 57.0% |
| **Non-Beneficial Uses:** | | | | | |
| Landfill | 29,565 | 5,005 | 34,570 | 41.7% | |
| Incineration[2] | 0 | 298 | 298 | 0.4% | |
| Subtotal | 29,565 | 9,464 | 34,868 | | 41.1% |
| **Total:** | 47,057 | 39,983 | 82,879 | 100% | 100% |
| **Total In & Out of State** | 56.8% | 48.2% | | | |

[1] All amounts of biosolids reported to DEC are converted from dry tons to wet tons assuming 15% solids (dry tons ÷ 0.15 = wet tons), which is generally the percent solids that can qualify to be landfilled.

[2] Note that nearly all biosolids sent to incinerators are in liquid form and the actual weight is greater than cited in this table. The table presents the approximate weight of the incinerated solids in wet tons. There are no incineration facilities located in Vermont.

# APPENDIX 4: Septage Management Statistics

**Table A-6: Vermont Septage Management Statistics for 2017**

| Management Option | In-State (gallons) | Out-of-State (gallons) | Total (gallons) | Percent of Total | Percent Managed |
|---|---|---|---|---|---|
| **Beneficial Uses:** | | | | | |
| Land Application[1] | 8,841,277 | 57,985 | 8,899,262 | 24.1% | |
| EQ Biosolids[2] | 9,342,205 | 2,752,230 | 12,094,435 | 32.7% | |
| Subtotal | 18,183,482 | 2,810,215 | 20,993,697 | | 56.8% |
| **Non-Beneficial Uses:** | | | | | |
| Landfill[3] | 15,692,772 | 14,000 | 15,706,772 | 42.5% | |
| Incineration[4] | 0 | 291,000 | 291,000 | 0.7% | |
| Subtotal | 15,620,792 | 305,000 | 15,997,772 | | 43.2% |
| **Total:** | 34,889,774 | 3,115,215 | 36,991,469 | 100% | 100% |
| **Percent of Total In & Out of State** | 94.3% | 5.7% | | | |

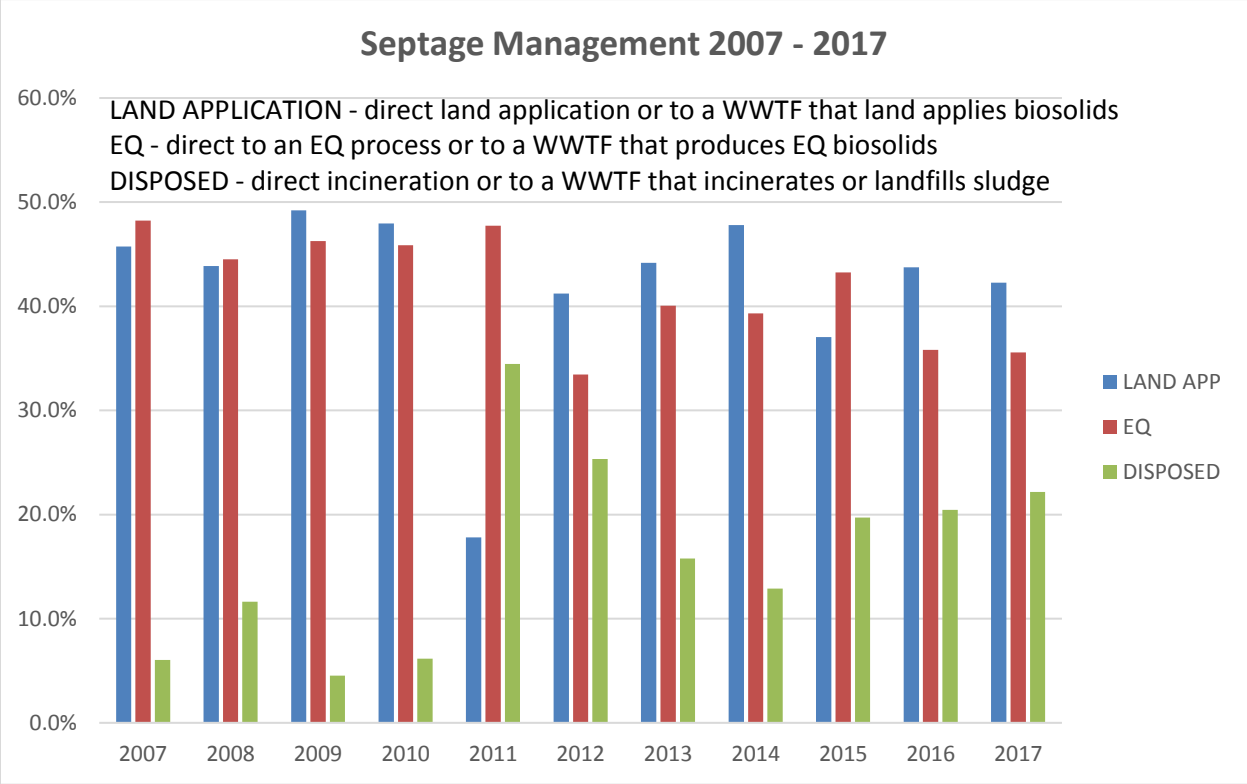
[1] Septage that is directly land applied or disposed at a WWTF that land applies the biosolids it produces.

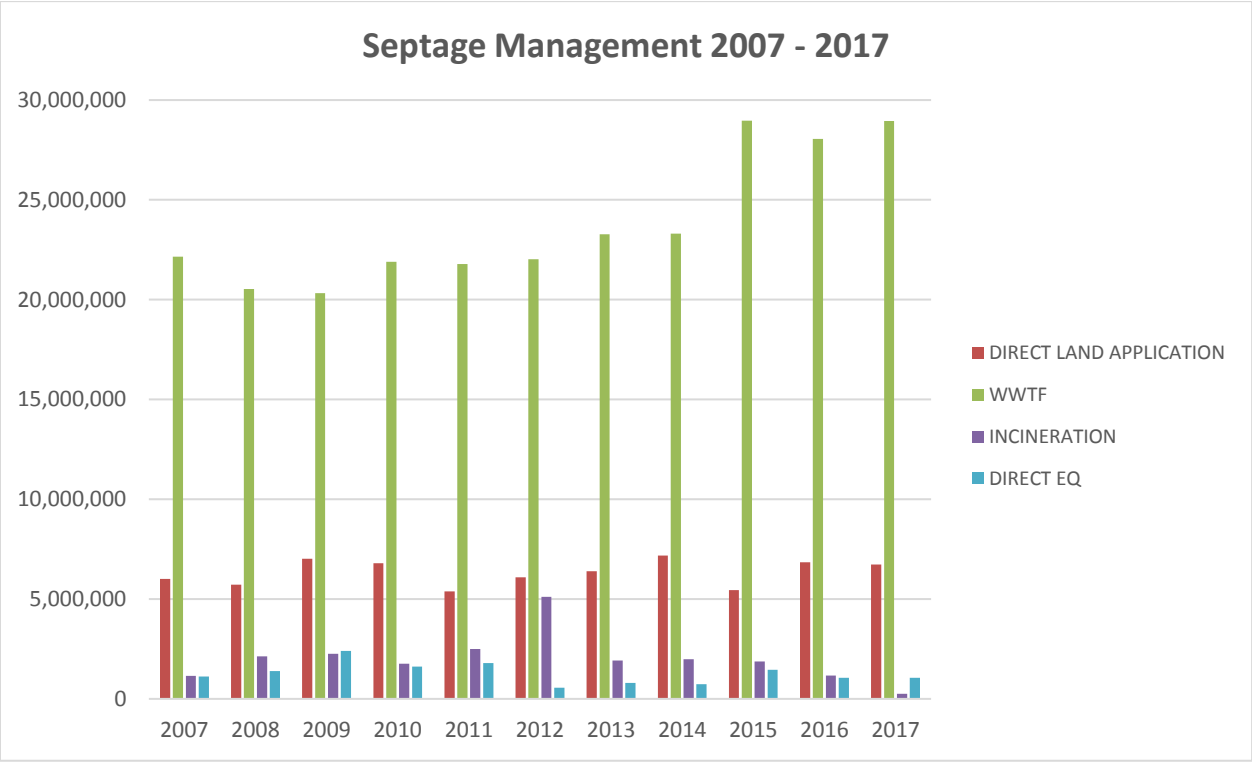
[2] Septage that is directly treated in an EQ process or disposed at a WWTF that produces EQ biosolids.

[3] Solids from dewatered septage that are disposed at a landfill or liquid septage disposed at a WWTF that landfills or incinerates sludge, converted back to gallons.

[4] There are no incineration facilities located in Vermont.

**Figure A-1: Historical Septage Management**



# APPENDIX 5: Radionuclides

**Table A-7: Information Regarding Commonly Detected Radionuclides**

| Isotope | Half-life | Exposure Media | Source | Origin |
|---|---|---|---|---|
| Be-7 | 53.22 days | Groundwater | Natural | Cosmic radiation |
| Bi-214 | 19.9 months | Groundwater | Natural | Uranium decay |
| I-131 | 8.0 days | Medical | Manmade | Manufactured |
| K-40 | $1.25 \times 10^9$ years | Groundwater/soil | Natural | Primordial |
| Pb-212 | 10.6 hours | Soil | Natural | Thorium decay |
| Pb-214 | 26.8 months | Soil | Natural | Uranium decay |
| Ra-226 | 1600 years | Groundwater/soil/air | Natural | Uranium decay |
| Ra-228 | 5.75 years | Groundwater/soil/air | Natural | Uranium decay |
| Sr-89 | 50.5 days | Soil/air/medical | Manmade | Manufactured/nuclear weapons fallout |
| Th-228 | 1.91 years | Soil/groundwater | Natural | Thorium decay |
| Tl-201 | 73 hours | Medical | Manmade | Manufactured |

# APPENDIX 6: Dioxin/PCB Toxicity Factors

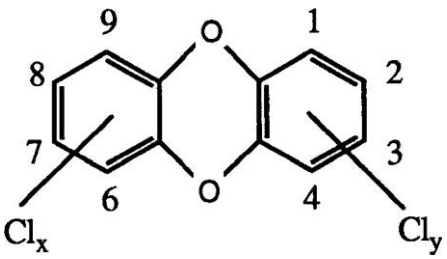
**Table A-8: PCDD and PCDF Toxic Equivalency Factors (TEFs)**

| CONGENER | WHO 2005 TEF (1989 NATO TEFs where different) |
|---|---|
| ***chlorinated dibenzo-p-dioxins*** | |
| 2,3,7,8-TCDD | 1.0 |
| 1,2,3,7,8-PeCDD | 1.0 (0.5) |
| 1,2,3,4,7,8-HxCDD | 0.1 |
| 1,2,3,6,7,8-HxCDD | 0.1 |
| 1,2,3,7,8,9-HxCDD | 0.1 |
| 1,2,3,4,6,7,8-HpCDD | 0.01 |
| OCDD | 0.0003 (0.001) |
| ***chlorinated dibenzofurans*** | |
| 2,3,7,8-TCDF | 0.1 |
| 1,2,3,7,8-PeCDF | 0.03 (0.05) |
| 2,3,4,7,8-PeCDF | 0.3 (0.5) |
| 1,2,3,4,7,8-HxCDF | 0.1 |
| 1,2,3,6,7,8-HxCDF | 0.1 |
| 1,2,3,7,8,9-HxCDF | 0.1 |
| 2,3,4,6,7,8-HxCDF | 0.1 |
| 1,2,3,4,6,7,8-HpCDF | 0.01 |
| 1,2,3,6,7,8,9-HpCDF | 0.01 |
| OCDF | 0.0003 (0.001) |
| ***non-ortho substituted PCBs*** | |
| 3,3'4,4'-tetraCB (PCB77) | 0.0001 |
| 3,4,4',5-tetraCB (PCB 81) | 0.0003 |
| 3,3',4,4',5-pentaCB (PCB126) | 0.1 |
| 3,3',4,4',5,5'-hexaCB (PCB169) | 0.03 |
| ***mono-ortho substituted PCBs*** | |
| 2,3,3',4,4'-pentaCB (PCB 105) | 0.0003 |
| 2,3,4,4',5-pentaCB (PCB 114) | 0.0003 |
| 2,3',4,4',5-pentaCB (PCB 118) | 0.0003 |
| 2',3,4,4',5-pentaCB (PCB 123) | 0.0003 |
| 2,3,3',4,4',5-hexaCB (PCB 156) | 0.0003 |
| 2,3,3',4,4',5'-hexaCB (PCB 157) | 0.0003 |
| 2,3',4,4',5,5'-hexaCB (PCB 167) | 0.0003 |
| 2,3,3',4,4',5,5'-heptaCB (PCB 189) | 0.0003 |

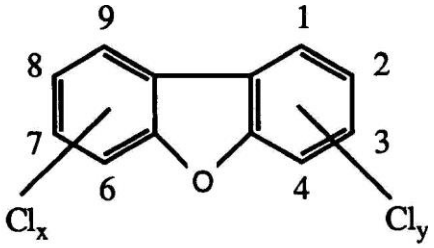
TEQ concentrations are calculated by multiplying the concentration of each PCDD/PCDF/PCB congener by its corresponding TEF and then summing the resulting numbers. TEQ concentrations are typically expressed as "parts per trillion TEQ".

T = tetra (4 Cl atoms at numbered positions)
Pe = penta (5 Cl atoms at numbered positions)
Hx = hexa (6 Cl atoms at numbered positions)
Hp = hepta (7 Cl atoms at numbered positions)
O = octa (8 Cl atoms at numbered positions)

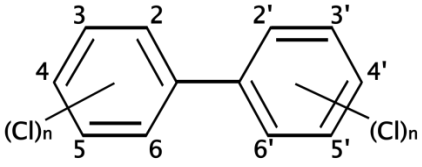
**Dibenzo-p-dioxin molecule**




**Dibenzofuran molecule**




**Biphenyl molecule**



# APPENDIX 7: State Biosolids Contaminant Limits

## Table A-9: U.S. States Ceiling Concentrations for Land Applied Non-EQ Biosolids

| STATE | NON-EQ BIOSOLIDS CEILING CONCENTRATIONS (Federal: 503.13 – Table 1) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | As | Cd | Cr | Cu | Pb | Hg | Mo | Ni | Se | Zn | OTHER |
| 503.13 – Table 1 | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Alabama | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Alaska | ***41*** | ***39*** | ***1200*** | ***1500*** | ***300*** | ***17*** | **75** | **420** | **100** | ***2800*** | |
| Arizona | 75 | 85 | ***3000*** | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Arkansas | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| California | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Colorado | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Connecticut | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Delaware | 75 | 85 | ***3000*** | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Florida | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Georgia | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Hawaii | ***20*** | ***15*** | ***200*** | ***1500*** | ***300*** | ***10*** | ***15*** | ***100*** | ***25*** | ***2000*** | |
| Idaho | 75 | 85 | ***3000*** | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Illinois [1] | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Indiana | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Iowa | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Kansas | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Kentucky | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Louisiana | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | ***PCB: 10*** |
| Maine [2] | ***41*** | ***39*** | ***3000*** | ***1500*** | ***300*** | ***10*** | 75 | 420 | 100 | ***2800*** | ***TCDD/F [2]*** |
| Maryland | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | ***PCB: 10*** |
| Massachusetts | 75 | 85 | ***1000*** | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | ***PCB: 10*** |
| Michigan | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Minnesota | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Mississippi | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Missouri | 75 | 85 | ***3000*** | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Montana | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Nebraska | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Nevada | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| New Hampshire [4] | ***32*** | ***14*** | ***1000*** | ***1500*** | ***300*** | ***10*** | ***35*** | ***200*** | ***28*** | ***2500*** | ***PCB: 1***<br>***TCDD/F [4]*** |
| New Jersey | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| New Mexico | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| New York | ***41*** | ***21*** | ***1000*** | ***1500*** | ***300*** | ***10*** | ***40*** | ***200*** | 100 | ***2500*** | |
| North Carolina | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| North Dakota | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Ohio | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Oklahoma | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Oregon | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Pennsylvania | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | ***PCB: 8.6*** |
| Rhode Island | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| South Carolina | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| South Dakota | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Tennessee | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Texas | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Utah | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Vermont | ***15*** | ***21*** | ***1000*** | ***1500*** | ***300*** | ***10*** | 75 | 420 | 100 | ***2800*** | ***PCB: 10*** |
| Virginia | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Washington | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| West Virginia | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Wisconsin | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |
| Wyoming | 75 | 85 | | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 | |

## Table A-10: U.S. States Concentration Limits for EQ Biosolids

| STATE | EQ BIOSOLIDS CONCENTRATION LIMITS (Federal: 503.13 - Table 3) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | As | Cd | Cr | Cu | Pb | Hg | Mo | Ni | Se | Zn | OTHER |
| 503.13 – Table 3 | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Alabama | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Alaska | 41 | 39 | ***1200*** | 1500 | 300 | 17 | ***75*** | 420 | 100 | 2800 | |
| Arizona | 41 | 39 | ***3000*** | 1500 | 300 | 17 | ***75*** | 420 | 100 | 2800 | |
| Arkansas | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| California | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Colorado | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Connecticut | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Delaware | 41 | 39 | ***1200*** | 1500 | 300 | 17 | ***18*** | 420 | ***36*** | 2800 | |
| Florida | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Georgia | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Hawaii | ***20*** | ***15*** | ***200*** | 1500 | 300 | ***10*** | ***15*** | ***100*** | ***25*** | ***2000*** | |
| Idaho | 41 | 39 | ***1200*** | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Illinois [1] | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Indiana | 41 | 39 | | 1500 | 300 | 17 | ***75*** | 420 | 100 | 2800 | |
| Iowa | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Kansas | 41 | 39 | | 1500 | 300 | 17 | ***75*** | 420 | 100 | 2800 | |
| Kentucky | 41 | 39 | | 1500 | 300 | 17 | ***75*** | 420 | 100 | 2800 | |
| Louisiana | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | ***PCB: 10*** |
| Maine [2] | 41 | 39 | ***3000*** | 1500 | 300 | ***10*** | ***75*** | 420 | 100 | 2800 | ***TCDD/F [2]*** |
| Maryland | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Massachusetts | 41 | ***14*** | ***1000*** | ***1000*** | 300 | ***10*** | ***25*** | ***200*** | 100 | ***2500*** | ***Boron: 300; PCB: 2*** |
| Michigan | 41 | 39 | | 1500 | 300 | 17 | ***75*** | 420 | 100 | 2800 | |
| Minnesota | 41 | 39 | | 1500 | 300 | 17 | ***75*** | 420 | 100 | 2800 | |
| Mississippi [3] | 41 | 39 | | 1500 | 300 | 17 | ***18*** | 420 | ***36*** | 2800 | |
| Missouri | 41 | 39 | ***1200*** | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Montana | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Nebraska | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Nevada | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| New Hampshire | ***10*** | ***10*** | ***160*** | ***1000*** | ***270*** | ***7*** | ***18*** | ***98*** | ***18*** | ***1780*** | ***PCB: 1; TCDD/F [4]*** |
| New Jersey | 41 | 39 | | 1500 | 300 | 17 | ***75*** | 420 | 100 | 2800 | |
| New Mexico | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| New York | 41 | ***10*** | ***1000*** | 1500 | 300 | ***10*** | ***40*** | ***200*** | 100 | ***2500*** | |
| North Carolina | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| North Dakota | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Ohio | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Oklahoma | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Oregon | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Pennsylvania | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | ***PCB: 4*** |
| Rhode Island | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| South Carolina | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| South Dakota | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Tennessee | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Texas | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Utah | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Vermont | ***15*** | ***21*** | ***1000*** | 1500 | 300 | ***10*** | ***75*** | 420 | 100 | 2800 | ***PCB: 10*** |
| Virginia | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Washington | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| West Virginia | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Wisconsin | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |
| Wyoming | 41 | 39 | | 1500 | 300 | 17 | | 420 | 100 | 2800 | |

**FOOTNOTES: Tables A-9 and A-10**

all standards are in units of (mg/kg, dry wt.) unless otherwise noted in a footnote below.
blank cells = no standard established under Part 503 or by the State.
normal font = State standard the same as 503.13 Table 1 or Table 3.
***bold italic font*** = State standard less than or in addition to 503.13 Table 1 or Table 3.

[1] Illinois:

Employs the 503 limits as screening standards, but regulates based on site specific APLR and CPLR limits.

[2] Maine:

Standards are based on monthly average concentrations.
Maine also employs screening standards for Non-EQ biosolids (lower than the ceiling concentration limits) which if exceeded mandate the implementation of additional land application site management practices.

TCDD/F: <27 ppt TEQ - no restrictions, 27 - 250 ppt TEQ – additional management practices and site title recording requirements apply, >250 ppt TEQ – prohibited.

[3] Mississippi:

For EQ, biosolids must first meet the standards cited in Table A-8. Secondly, if the biosolids exceed any of the following contaminant concentrations (mg/kg, dry wt.): As: 10, Ba: 200, Cd: 2, Cr: 10, Pb: 10, Hg: 0.4, Se: 2, Ag: 10 - the biosolids must be subjected to and pass a TCLP analysis for the contaminant(s) exceeded.

[4] New Hampshire:

10 ppt TEQ for 2,3,7,8 TCDD and 2,3,7,8 TCDF individually, 27 ppt TEQ total for all congeners of TCDD and TCDF with an assigned TEF.

# APPENDIX 8: International Biosolids Contaminant Limits

## Table A-9: Regulatory Limits for Agricultural Use in Selected Nations and Provinces

| COUNTRY/PROVINCE | REGULATORY LIMIT FOR AGRICULTURAL USE (mg/kg, dry wt.) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | As | Ba | Cd | Co | Cr | Cu | Pb | Hg | Mo | Ni | Se | Zn |
| Australia (Class 1) | 20 | | 3 | | 100 | 100 | 150 | 1 | | 60 | 3 | 200 |
| Australia (Class 2) | 60 | | 20 | | 500 | 2500 | 420 | 15 | | 270 | 50 | 2500 |
| Brazil | 41 | 1300 | 39 | | 1000 | 1500 | 300 | 17 | 50 | | 100 | 2800 |
| Bulgaria | 30 | | 30 | | 500 | 1500 | 1000 | 16 | | 300 | | 3000 |
| Canada - British Colombia | 75 | | 20 | 150 | 1060 | 2200 | 500 | 5 | 20 | 180 | 14 | 1850 |
| Canada - New Brunswick | | | 20 | | | 888 | 56 | 3.1 | 7.6 | 26.4 | 4.2 | 588 |
| Canada - Ontario | 170 | | 34 | 340 | 2800 | 1700 | 1100 | 11 | | 420 | | 4200 |
| Canada - Quebec (Class 1) | 13 | | 3 | 34 | 210 | 400 | 150 | 0.8 | 5 | 62 | 2 | 700 |
| Canada - Quebec (Class 2) | 40 | | 10 | 150 | 1060 | 1000 | 300 | 4 | 20 | 180 | 14 | 1850 |
| Canada - Saskatchewan | 75 | | 20 | 150 | 1060 | 760 | 500 | 5 | 20 | 180 | 14 | 1850 |
| Canada (Class A) | 13 | | 3 | 34 | 210 | 400 | 150 | 0.8 | 5 | 62 | 2 | 700 |
| China | 75 | 150 | 5 | | 600 | 800 | 300 | 5 | | 100 | | 2000 |
| Czech Republic | 30 | | 5 | | 200 | 500 | 200 | 4 | | 100 | | 2500 |
| Finland | 25 | | 1.5 | | 300 | 600 | 100 | 1 | | 100 | | 1500 |
| Germany | | | 10 | | 900 | 800 | 900 | 8 | | 200 | | 2500 |
| Hungary | 75 | | 10 | 50 | 1000 | 1000 | 750 | 10 | 20 | 200 | 100 | 2500 |
| Italy | | | 20 | | | 1000 | 750 | 10 | | 300 | | 2500 |
| Japan | 50 | | 5 | | 500 | | 100 | 2 | | 300 | | |
| Jordan (Type 1) | 41 | | 40 | | 900 | 1500 | 300 | 17 | 75 | 300 | 100 | 1800 |
| Jordan (Type 2) | 75 | | 40 | | 900 | 3000 | 840 | 57 | 75 | 400 | 100 | 4000 |
| Jordan (Type 3) | 75 | | 85 | | 3000 | 4300 | 840 | 57 | 75 | 420 | 100 | 7500 |
| Mexico | 41 | | 39 | | 1200 | 1500 | 300 | 17 | | 420 | | 2800 |
| Netherlands | 15 | | 1.25 | | 75 | 75 | 100 | 0.75 | | 30 | | 300 |
| New Zealand (Grade A) | 20 | | 3 | | 600 | 100 | 300 | 1 | | 60 | | 300 |
| New Zealand (Grade B) | 30 | | 10 | | 1500 | 1250 | 300 | 7.5 | | 135 | | 1500 |
| Norway | | | 2 | | 100 | 650 | 80 | 3 | | 50 | | 800 |
| Russia | 10 | | 15 | | 500 | 750 | 250 | 7.5 | | 200 | | 1750 |
| Slovakia | 20 | | 10 | | 1000 | 1000 | 750 | 10 | | 300 | | 2500 |
| Slovenia | 20 | | 0.5 | | 40 | 30 | 40 | 0.2 | | 30 | | 100 |
| South Africa (Class A) | 40 | | 40 | | 1200 | 1500 | 300 | 15 | | 420 | | 2800 |
| Switzerland | | | 5 | 60 | 500 | 600 | 500 | 5 | 20 | 80 | | 2000 |
| Turkey | | | 40 | | 1200 | 1750 | 1200 | 25 | | 400 | | 4000 |
| Vermont | 15 | | 21 | | 1200 | 1500 | 300 | 10 | 75 | 420 | 100 | 2800 |

blank cells = no regulatory standard adopted

Source: U.N. - Human Settlements Programme and Greater Moncton Sewerage Commission (2008). "Global Atlas of Excretia, Wastewater Sludge, and Biosolids Management: Moving Forward the Sustainable and Welcome Uses of a Global Resource".

**APPENDIX 9: 1997 Biosolis Pollutant Survey Data**

VERMONT WWTF BIOSOLIDS SAMPLING PROJECT
FINAL REPORT
JUNE 10, 1997

TOTAL NUMBER OF SAMPLES = 83

METALS
(mg/kg, dry wt.)

| | MEAN | MEDIAN | STD. DEV. | MINIMUM | MAXIMUM | 90th %ile CONC. | # OF DETECTS | PERCENT DETECTS | P(CONC.< VT STD.) | P(CONC.< EQ STD.) | PQL | TCLP MAX. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Antimony | 7.41 | 5.00 | 6.51 | 5.00 | 25.00 | 25.00 | 83 | 100.00 | | | 5.00 / 25.00 | |
| Arsenic | 10.47 | 10.00 | 2.37 | 10.00 | 29.00 | 10.00 | 83 | 100.00 | 1.00 | | 10.00 | 0.59 |
| Barium | 442.81 | 385.00 | 279.11 | 120.00 | 1,460.00 | 750.20 | 83 | 100.00 | | | 0.00 | 25.02 |
| Beryllium | 0.56 | 0.50 | 0.49 | 0.50 | 5.00 | 0.50 | 83 | 100.00 | | | 0.50 | |
| Cadmium | 6.08 | 5.00 | 4.85 | 5.00 | 44.00 | 6.00 | 83 | 100.00 | 0.99 | 1.00 | 5.00 | 0.60 |
| Chromium | 58.69 | 50.00 | 25.93 | 50.00 | 166.00 | 67.80 | 83 | 100.00 | 1.00 | 1.00 | 50.00 | 6.78 |
| Copper | 783.80 | 658.00 | 466.93 | 156.00 | 2,620.00 | 1,278.00 | 83 | 100.00 | 0.67 | 0.94 | 50.00 | |
| Lead | 112.14 | 94.00 | 81.31 | 50.00 | 549.00 | 174.40 | 83 | 100.00 | 1.00 | 0.99 | 50.00 | 8.47 |
| Mercury | 2.58 | 1.84 | 2.03 | 1.00 | 11.10 | 5.72 | 83 | 100.00 | 0.99 | 1.00 | 1.00 | 0.27 |
| Molybdenum | 15.54 | 6.00 | 45.21 | 5.00 | 408.00 | 24.60 | 83 | 100.00 | | 0.52 | 5.00 | |
| Nickel | 34.82 | 25.00 | 25.02 | 25.00 | 174.00 | 50.60 | 83 | 100.00 | 1.00 | 1.00 | 50.00 | 4.88 |
| Selenium | 5.07 | 5.00 | 0.34 | 5.00 | 7.00 | 5.00 | 83 | 100.00 | | 1.00 | 5.00 | 0.22 |
| Silver | 35.86 | 16.30 | 41.39 | 5.00 | 210.00 | 104.20 | 83 | 100.00 | | | 5.00 | 3.81 |
| Thallium | 1.00 | 1.00 | 0.03 | 1.00 | 1.20 | 1.00 | 83 | 100.00 | | | 1.00 | |
| Zinc | 994.52 | 844.00 | 554.87 | 139.00 | 2,670.00 | 1,798.00 | 83 | 100.00 | 0.99 | 0.99 | 50.00 | 60.44 |

SOLIDS
(% wt.)

| | MEAN | MEDIAN | STD. DEV. | MINIMUM | MAXIMUM | 90th %ile CONC. | # OF DETECTS | PERCENT DETECTS | P(CONC.< VT STD.) | P(CONC.< EQ STD.) | PQL | TCLP MAX. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Percent | 3.14 | 2.42 | 3.10 | 0.63 | 25.00 | 5.63 | 83 | 100.00 | | | | |

NUTRIENTS
(% wt.)

| | MEAN | MEDIAN | STD. DEV. | MINIMUM | MAXIMUM | 90th %ile CONC. | # OF DETECTS | PERCENT DETECTS | P(CONC.< VT STD.) | P(CONC.< EQ STD.) | PQL | TCLP MAX. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrate | 0.0474 | 0.0024 | 0.131 | 0.00004 | 0.688 | 0.209 | 83 | 100.00 | | | | |
| TKN | 5.05014 | 5.2043 | 2.198 | 1.26740 | 12.718 | 7.723 | 83 | 100.00 | | | | |
| Phosphorus | 2.4463 | 1.888 | 1.891 | 0.44950 | 9.581 | 4.311 | 83 | 100.00 | | | | |

VERMONT WWTF BIOSOLIDS SAMPLING PROJECT
FINAL REPORT
JUNE 10, 1997

TOTAL NUMBER OF SAMPLES = 83

VOLATILE ORGANICS
(mg/kg, dry wt.)

| | MEAN | MEDIAN | STD. DEV. | MINIMUM | MAXIMUM | 90th %ile CONC. | # OF DETECTS | PERCENT DETECTS | P(CONC.< VT STD.) | P(CONC.< EQ STD.) | PQL | TCLP MAX. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vinyl chloride | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Chloromethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Bromomethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Chloroethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Trichlorofluoromethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Acetone | 1.645 | 0.0 | 6.076 | 0.0 | 43.60 | 2.108 | 17 | 0.48 | | | | |
| 1,1'-Dichloroethene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Carbon disulfide | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Methylene chloride | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Methyl-t-butylether | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 1,2-Dichloroethene | 0.003 | 0.0 | 0.017 | 0.0 | 0.122 | 0.0 | 2 | 2.41 | | | | |
| 1,1-dichloroethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Vinyl acetate | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2-butanone | 0.682 | 0.0 | 3.654 | 0.0 | 29.80 | 0.0 | 6 | 7.23 | | | | 0.49 |
| Chloroform | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 1,1,1-trichloroethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Carbon tetrachloride | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Benzene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 1,2-dichloroethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Trichloroethene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 1,2-dichloropropane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Bromodichloromethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 4-methyl-2-pentanone | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Cis-1,2-dichloropropene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Toluene | 31.863 | 0.002 | 106.976 | 0.0 | 564.000 | 47.160 | 43 | 51.81 | | | | |
| Trans-1,3-dichloropropene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 1,1,2-trichloroethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2-hexanone | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Tetrachloroethene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Dibromochloromethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Chlorobenzene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Ethylbenzene | 0.012 | 0.0 | 0.052 | 0.0 | 0.251 | 0.0 | 4 | 4.82 | | | | |
| Xylenes (total) | 0.046 | 0.0 | 0.208 | 0.0 | 1.080 | 0.0 | 4 | 4.82 | | | | |
| Styrene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Bromoform | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 1,1,2,2-tetrachloroethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| TVH | 554.960 | 0.0 | 2,154.293 | 0.0 | 14,300.000 | 366.600 | 26 | 31.33 | | | | |

VERMONT WWTF BIOSOLIDS SAMPLING PROJECT
FINAL REPORT
JUNE 10, 1997

TOTAL NUMBER OF SAMPLES = 83

PCB/PESTICIDES
(mg/kg, dry wt.)

| | MEAN | MEDIAN | STD. DEV. | MINIMUM | MAXIMUM | 90th %ile CONC. | # OF DETECTS | PERCENT DETECTS | P(CONC.< VT STD.) | P(CONC.< EQ STD.) | PQL | TCLP MAX. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aldrin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| alpha-BHC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| beta-BHC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| delta-BHC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Lindane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Chlorodane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 4,4'-DDD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 4,4'-DDE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 4,4'-DDT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Dieldrin | 0.00001 | 0.0 | 0.00013 | 0.0 | 0.00121 | 0.0 | 1 | 1.20 | | | | |
| Endosulfan I | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Endosulfan II | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Endosulfan sulfate | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Endrin | 0.00003 | 0.0 | 0.00026 | 0.0 | 0.00234 | 0.0 | 1 | 1.20 | | | | |
| Endrin aldehyde | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Heptachlor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Heptachlor epoxide | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Methoxychlor | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Toxaphene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| PCB | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Dursban | 0.015 | 0.0 | 0.100 | 0.0 | 0.903 | 0.005 | 39 | 46.99 | 1.00 | | | |

VERMONT WWTF BIOSOLIDS SAMPLING PROJECT
FINAL REPORT
JUNE 10, 1997

TOTAL NUMBER OF SAMPLES = 83

SEMIVOLATILE ORGANICS
(mg/kg, dry wt.)

| MAX. | MEAN | MEDIAN | STD. DEV. | MINIMUM | MAXIMUM | 90th %ile CONC. | # OF DETECTS | PERCENT DETECTS | P(CONC.< VT STD.) | P(CONC.< EQ STD.) | PQL | TCLP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N-nitrosodimethylamine | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Analine | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Phenol | 0.236 | 0.0 | 0.993 | 0.0 | 6.500 | 0.387 | 11 | 13.25 | | | | |
| Bis(2-chloroethyl)ether | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2-chlorophenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 1,3-dichlorobenzene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 1,4-dichlorobenzene | 0.060 | 0.0 | 0.546 | 0.0 | 5.000 | 0.0 | 1 | 1.20 | | | | 0.15 |
| 1,2-dichlorobenzene | 0.072 | 0.0 | 0.655 | 0.0 | 6.000 | 0.0 | 1 | 1.20 | | | | |
| Benzyl alcohol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2-methylphenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Bis(2-chloroisopropyl)ether | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Hexachloroethane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 4-methylphenol | 6.873 | 0.0 | 49.077 | 0.0 | 50.000 | 4.837 | 27 | 32.53 | | | | 13.34 |
| N-nitroso-di-n-propylamine | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Nitrobenzene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Isophorone | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2-nitrophenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2,4-dimethylphenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Bis(2-chloroethoxy)methane | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2,4-dichlorophenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 1,2,4-trichlorobenzene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Naphthalene | 0.072 | 0.0 | 0.655 | 0.0 | 6.000 | 0.0 | 1 | 1.20 | | | | |
| Benzoic acid | 0.654 | 0.0 | 5.457 | 0.0 | 50.000 | 0.0 | 4 | 4.82 | | | | |
| 4-chloroanaline | 0.310 | 0.0 | 2.024 | 0.0 | 15.750 | 0.0 | 2 | 2.41 | | | | |
| Hexachlorobutadiene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 4-chloro-3-methylphenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2-methylnaphthalene | 0.072 | 0.0 | 0.655 | 0.0 | 6.000 | 0.0 | 1 | 1.20 | | | | |
| Hexachlorocyclopentadiene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2,4,6-trichlorophenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 2,4,5-trichlorophenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 2-chloronaphthalene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2-nitroanaline | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Acenaphthalene | 0.072 | 0.0 | 0.655 | 0.0 | 6.000 | 0.0 | 1 | 1.20 | | | | |
| Dimethylphthalate | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2,6-dinitrotoluene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Acenaphthene | 0.072 | 0.0 | 0.655 | 0.0 | 6.000 | 0.0 | 1 | 1.20 | | | | |
| 3-nitroanaline | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 2,4-dinitrophenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Dibenzofuran | 0.072 | 0.0 | 0.655 | 0.0 | 6.000 | 0.0 | 1 | 1.20 | | | | |
| 2,4-dinitrotoluene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| 4-nitrophenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |

VERMONT WWTF BIOSOLIDS SAMPLING PROJECT
FINAL REPORT
JUNE 10, 1997

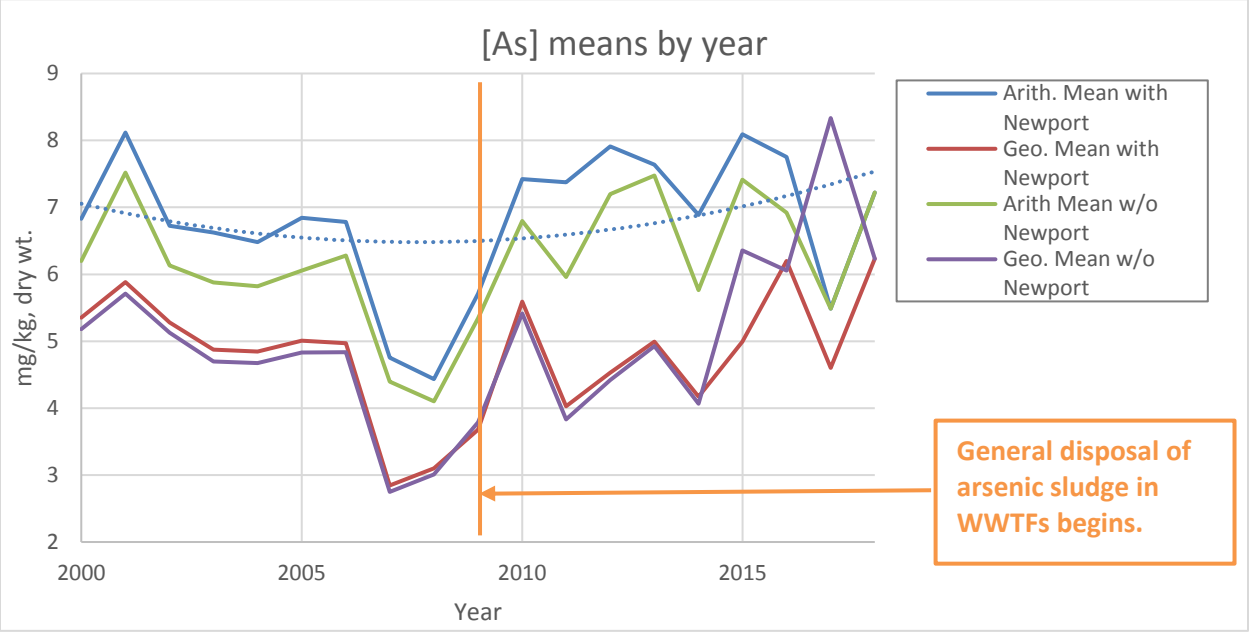
TOTAL NUMBER OF SAMPLES = 83

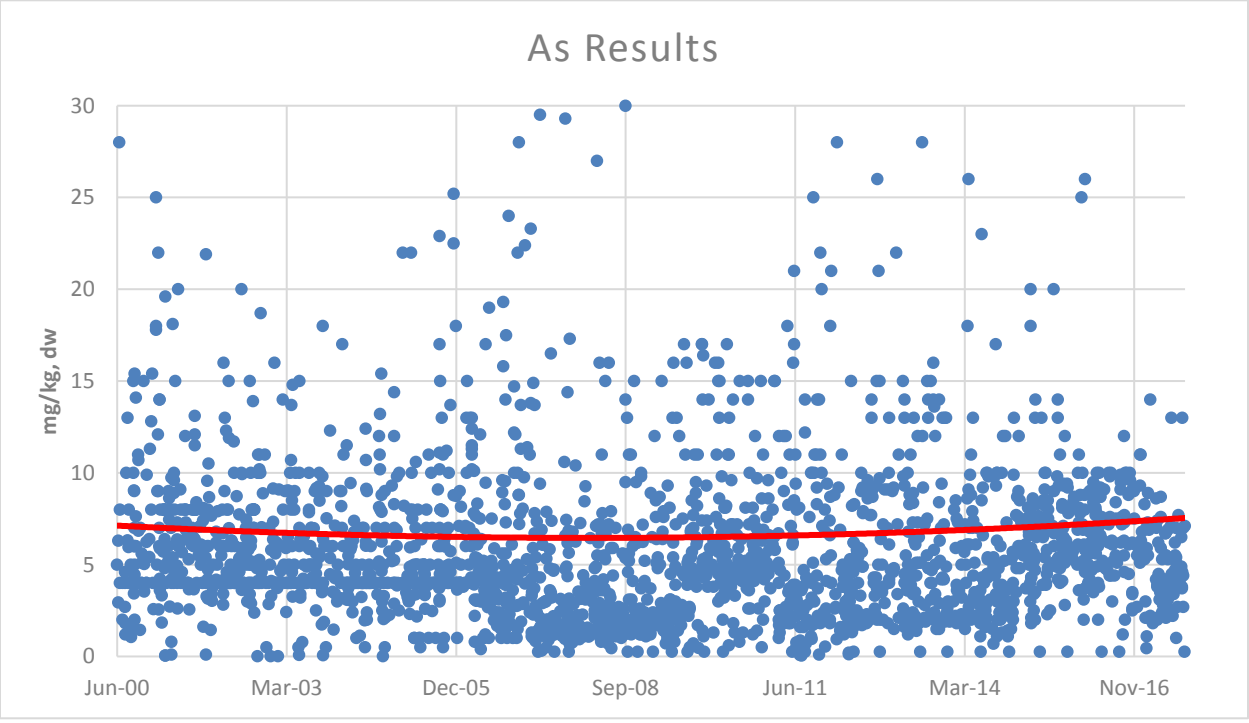
SEMIVOLATILE ORGANICS (con't.)
(mg/kg, dry wt.)

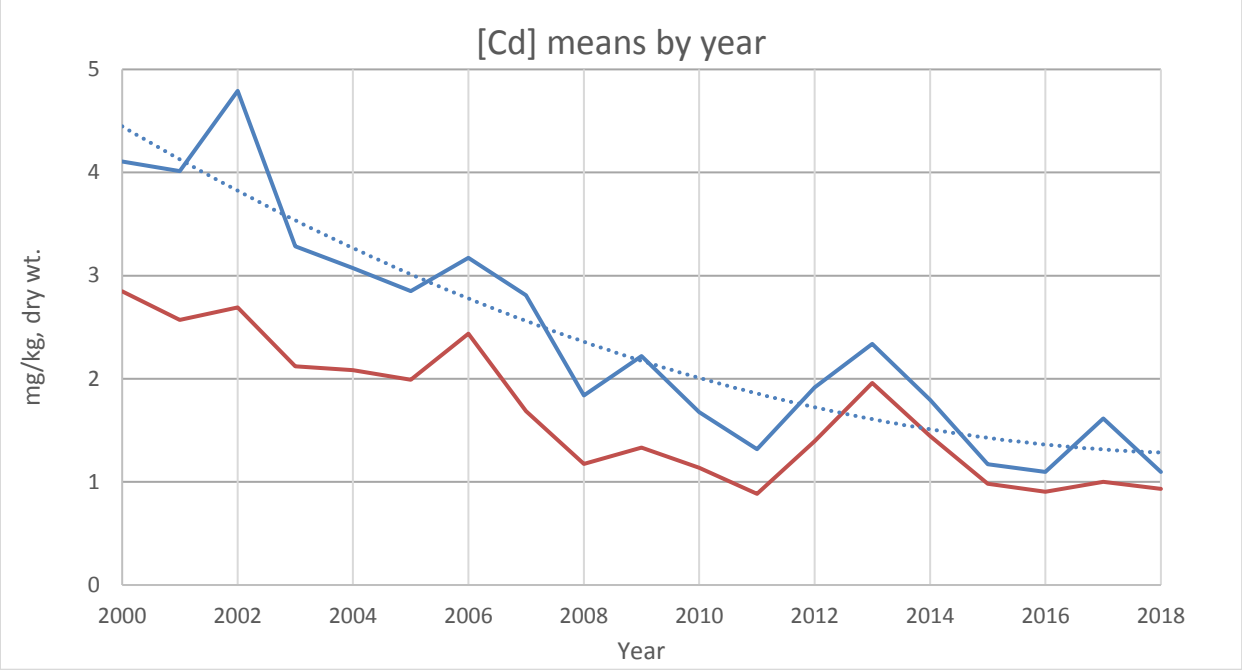
| MAX. | MEAN | MEDIAN | STD. DEV. | MINIMUM | MAXIMUM | 90th %ile CONC. | # OF DETECTS | PERCENT DETECTS | P(CONC.< VT STD.) | P(CONC.< EQ STD.) | PQL | TCLP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fluorene | 0.072 | 0.0 | 0.655 | 0.0 | 6.000 | 0.0 | 1 | 1.20 | | | | |
| 4-chlorophenyl phenyl ether | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Diethylphthalate | 0.026 | 0.0 | 0.238 | 0.0 | 2.180 | 0.0 | 1 | 1.20 | | | | |
| 4-nitroanaline | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 4,6-dinitro-2-methylphenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| N-nitrosodiphenylamine | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Azobenzene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| 4-bromophenyl phenyl ether | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Hexachlorobenzene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Pentachlorophenol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | 0.0 |
| Phenanthrene | 0.224 | 0.0 | 1.402 | 0.0 | 10.000 | 0.0 | 5 | 6.02 | | | | |
| Anthracene | 0.197 | 0.0 | 1.265 | 0.0 | 10.000 | 0.0 | 5 | 6.02 | | | | |
| Di-n-butylphthalate | 124.237 | 0.0 | 1,123.726 | 0.0 | 10,300.000 | 0.0 | 2 | 2.41 | | | | |
| Fluoranthene | 0.618 | 0.0 | 3.045 | 0.0 | 20.000 | 0.085 | 12 | 14.46 | | | | |
| Pyrene | 0.688 | 0.0 | 3.306 | 0.0 | 20.000 | 0.085 | 12 | 14.46 | | | | |
| Butyl benzyl phthalate | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Benzo[a]anthracene | 0.279 | 0.0 | 1.547 | 0.0 | 12.000 | 0.0 | 5 | 6.02 | | | | |
| Chrysene | 0.255 | 0.0 | 1.369 | 0.0 | 10.000 | 0.0 | 5 | 6.02 | | | | |
| 3,3'-dichlorobenzidine | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Bis(2-ethylhexyl)phthalate | 7.499 | 0.0 | 43.013 | 0.0 | 373.000 | 1.016 | 34 | 40.96 | | | | |
| Benzo[b]fluoranthene | 0.386 | 0.0 | 2.531 | 0.0 | 20.000 | 0.0 | 3 | 3.61 | | | | |
| Benzo[k]fluoranthene | 0.121 | 0.0 | 1.091 | 0.0 | 10.000 | 0.0 | 2 | 2.41 | | | | |
| Di-n-octylphthalate | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| benzo[a]pyrene | 0.133 | 0.0 | 1.200 | 0.0 | 11.000 | 0.0 | 2 | 2.41 | | | | |
| Indeno[1,2,3,cd]pyrene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| Dibenz[a,h]anthracene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| benzo[g,h,i]perylene | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | | | | |
| C-3 alkylbenzene isomers | 0.003 | 0.0 | 0.028 | 0.0 | 0.252 | 0.0 | 1 | 1.20 | | | | |
| C-4 alkylbenzene isomers | 0.079 | 0.0 | 0.656 | 0.0 | 6.000 | 0.0 | 3 | 3.61 | | | | |
| 1-methylnaphthalene | 0.072 | 0.0 | 0.655 | 0.0 | 6.000 | 0.0 | 0 | 1.20 | | | | |
| Dimethylnaphthalene isomers | 0.135 | 0.0 | 1.222 | 0.0 | 11.200 | 0.0 | 1 | 1.20 | | | | |
| Trimethylnaphthalene isomers | 0.102 | 0.0 | 0.927 | 0.0 | 8.500 | 0.0 | 1 | 1.20 | | | | |

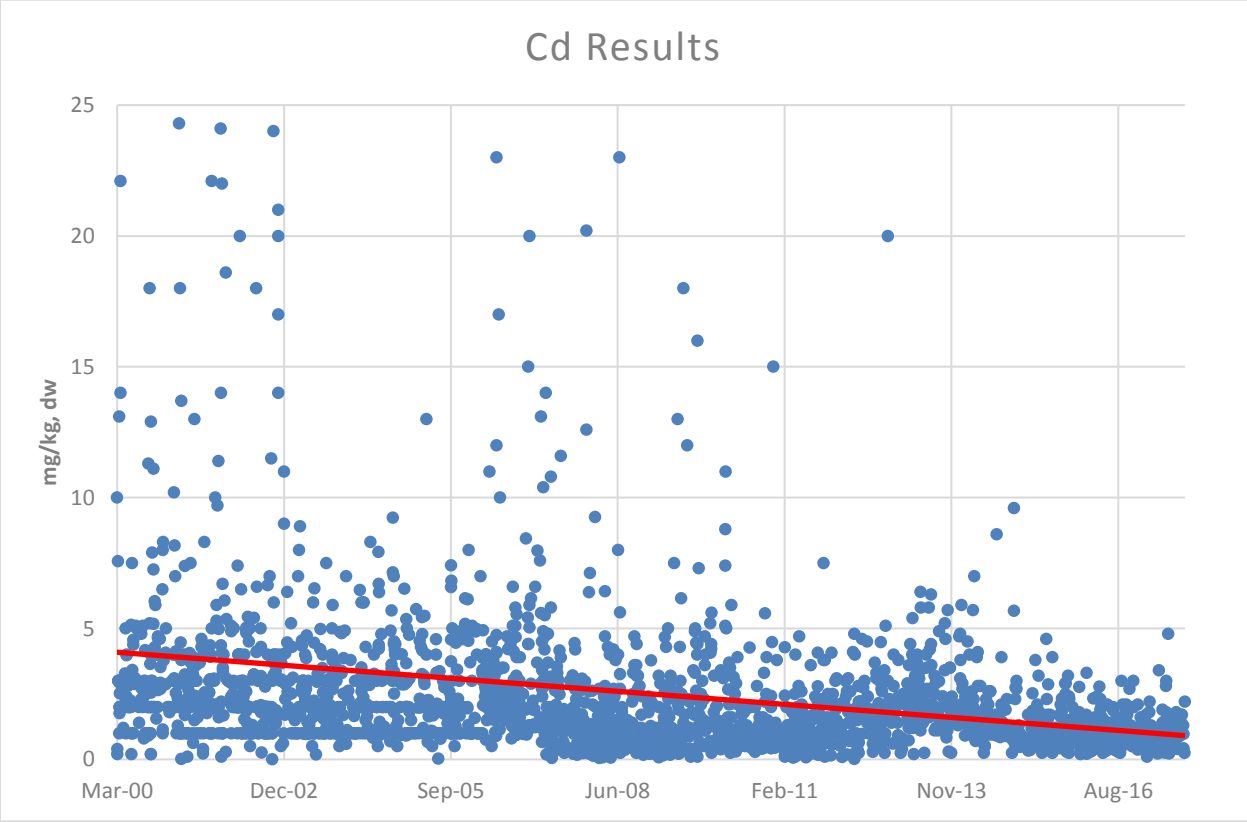
# APPENDIX 10: Trends in Metal Pollutant Concentrations in Vermont Biosolids

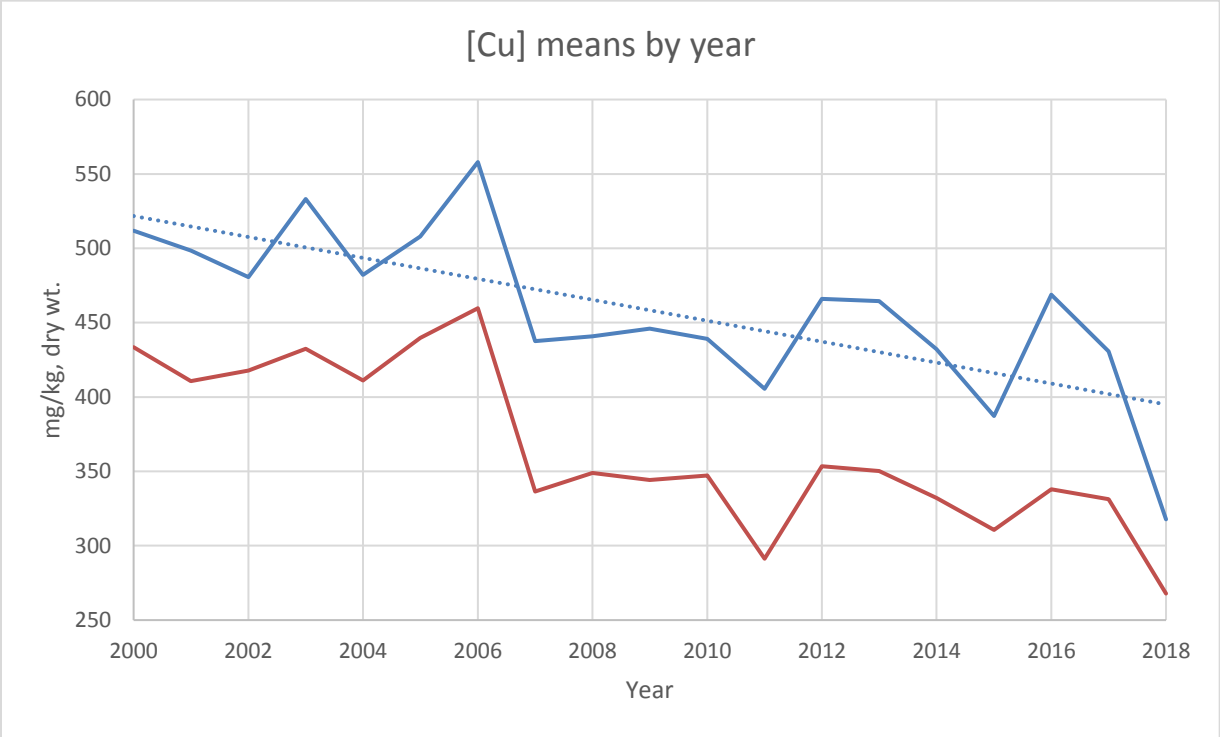
Blue lines = arithmetic mean
Red lines = geometric mean

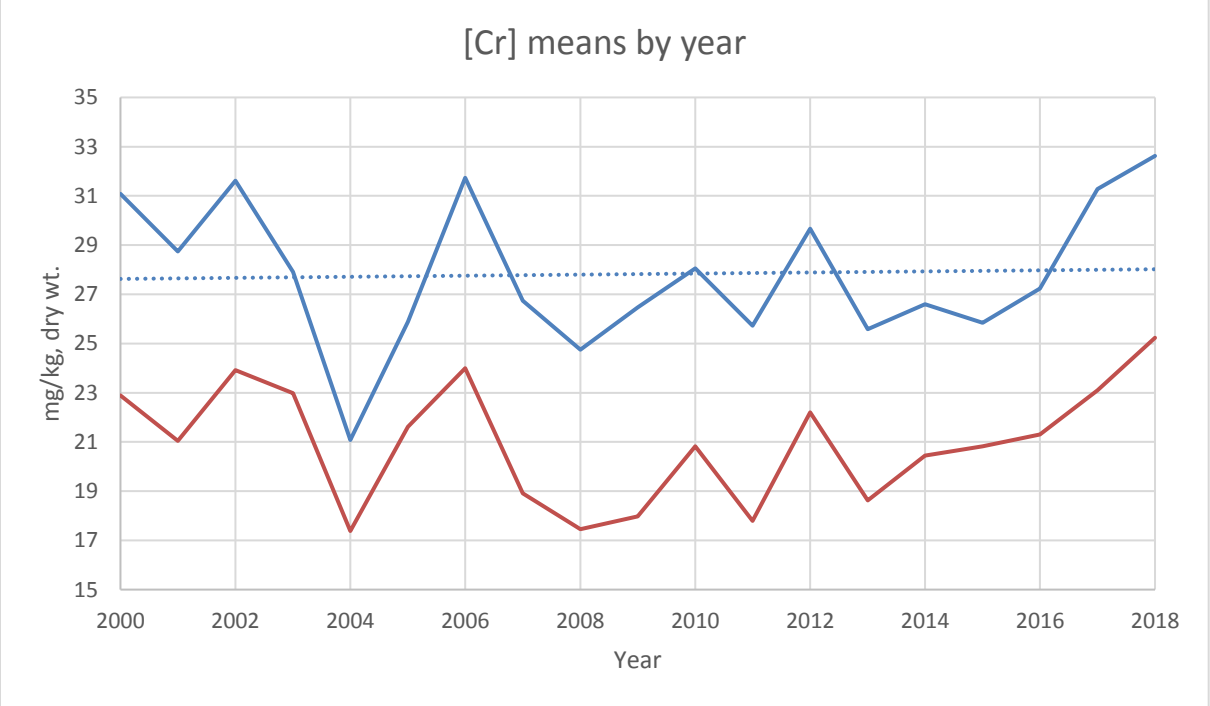


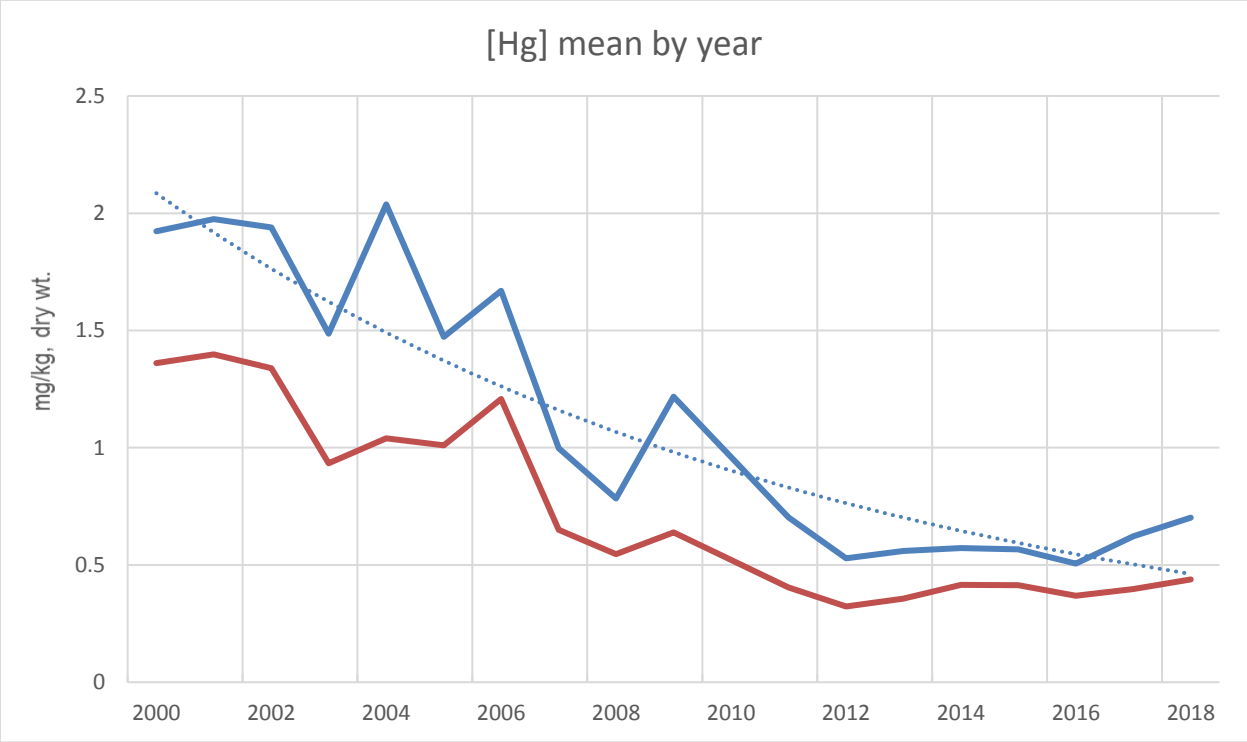



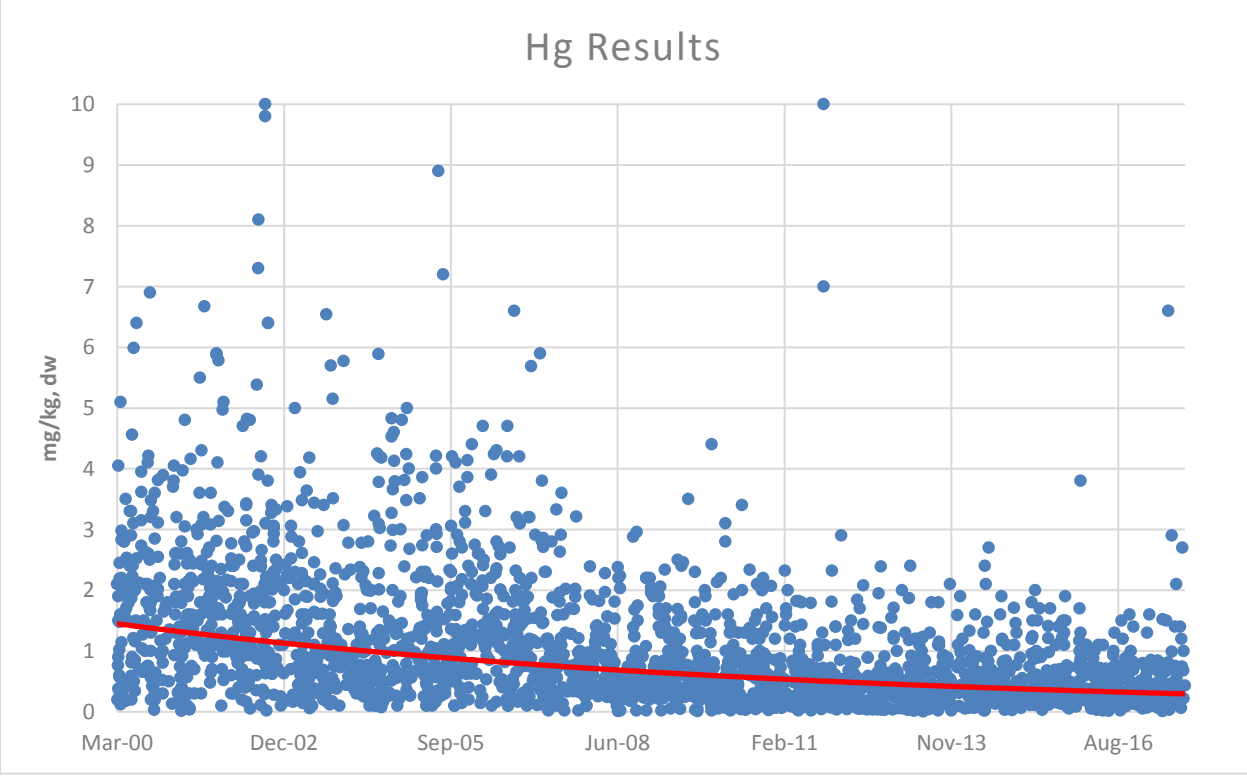

[Cd] means by year
mg/kg, dry wt.
0
1
2
3
4
5
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year

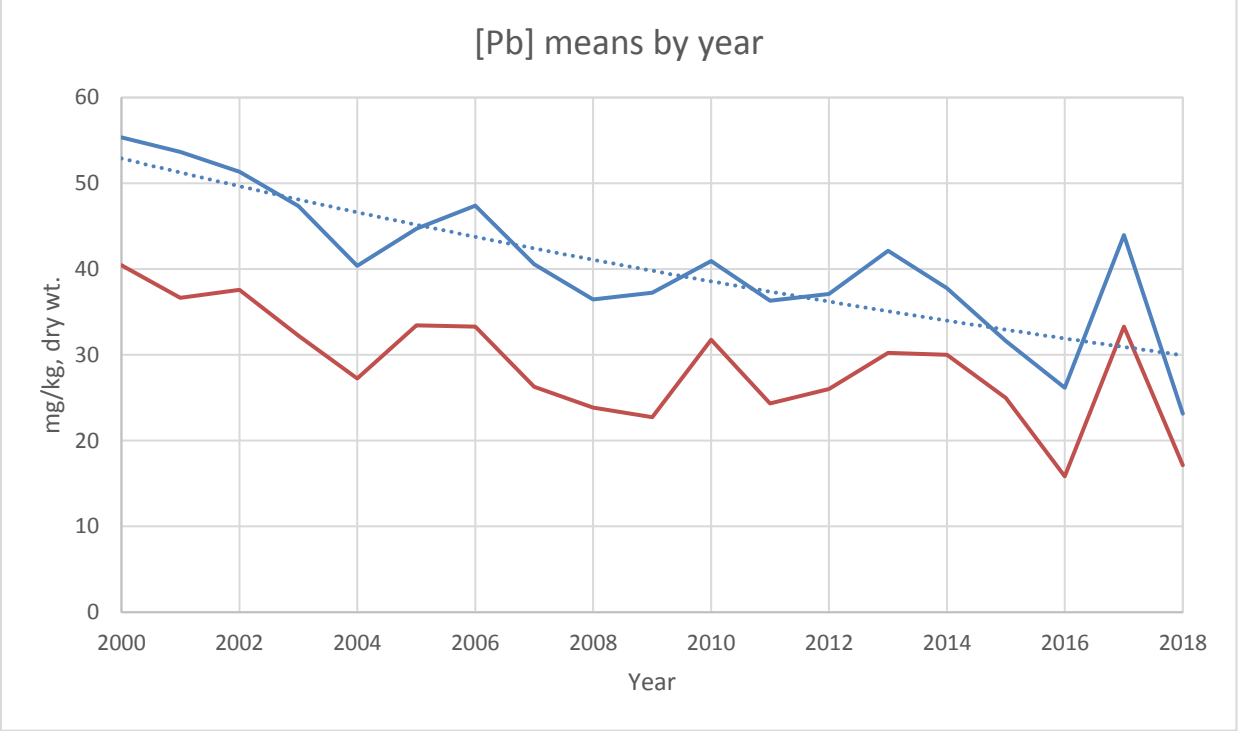

Cd Results
mg/kg, dw
0
5
10
15
20
25
Mar-00
Dec-02
Sep-05
Jun-08
Feb-11
Nov-13
Aug-16

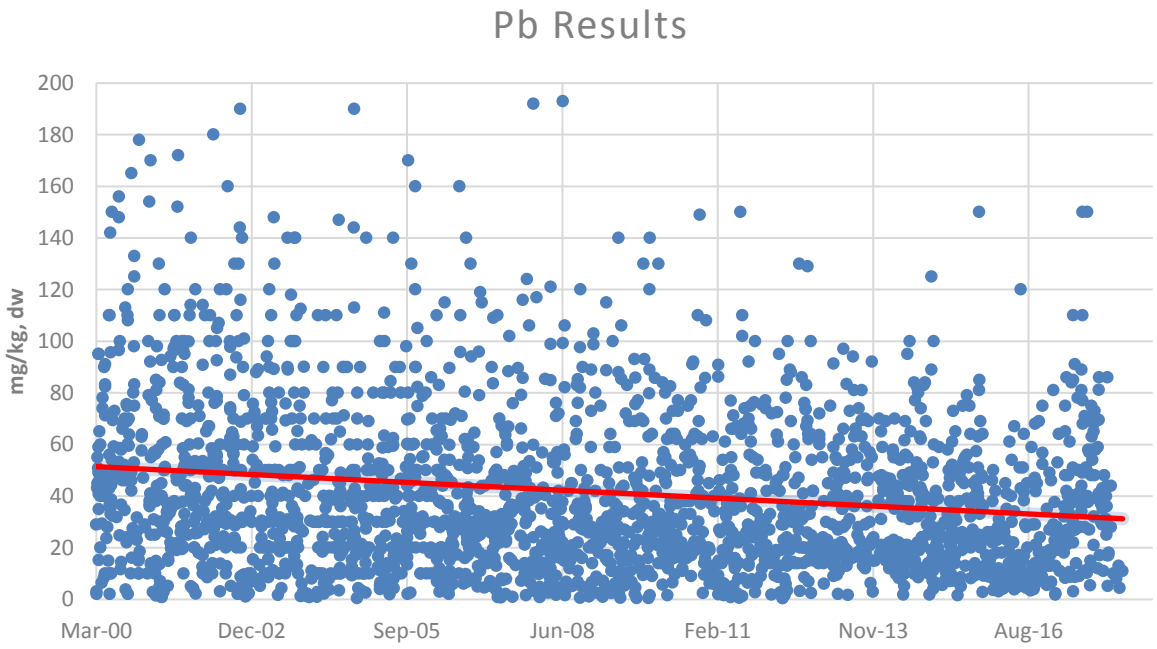

[Cu] means by year
mg/kg, dry wt.
600
550
500
450
400
350
300
250
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year

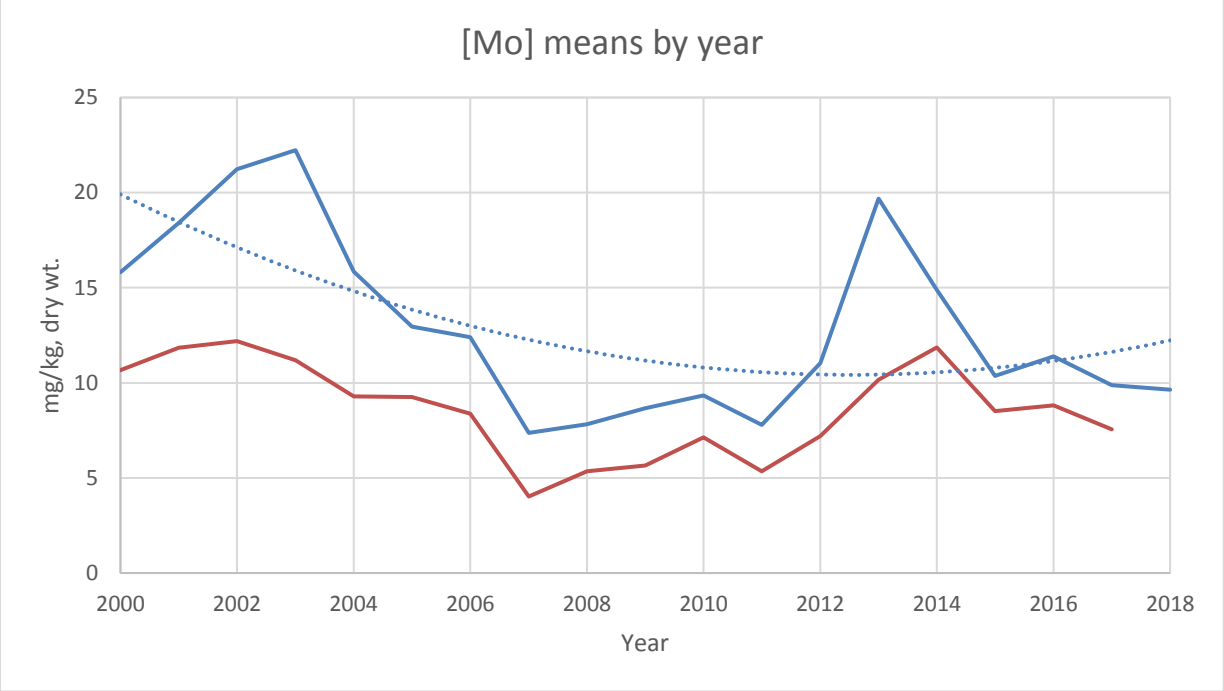

[Cr] means by year
mg/kg, dry wt.
35
33
31
29
27
25
23
21
19
17
15
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year

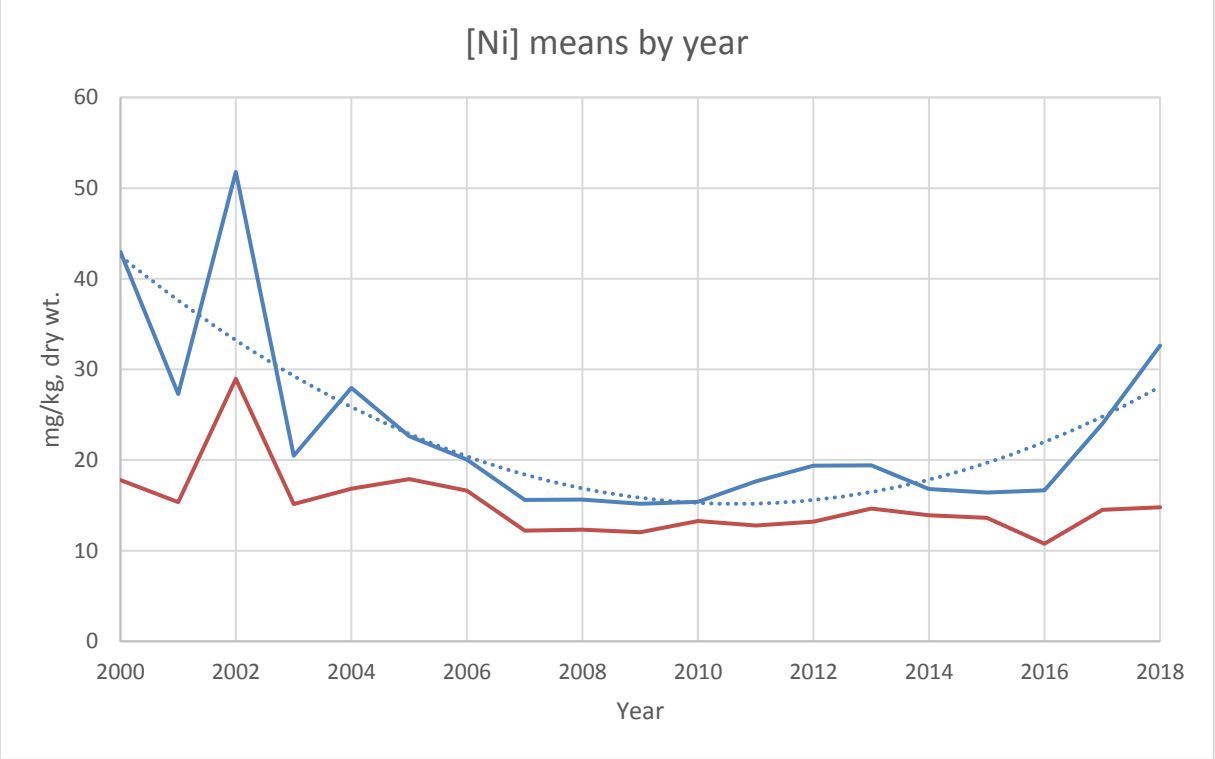

[Hg] mean by year
mg/kg, dry wt.
2.5
2
1.5
1
0.5
0
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

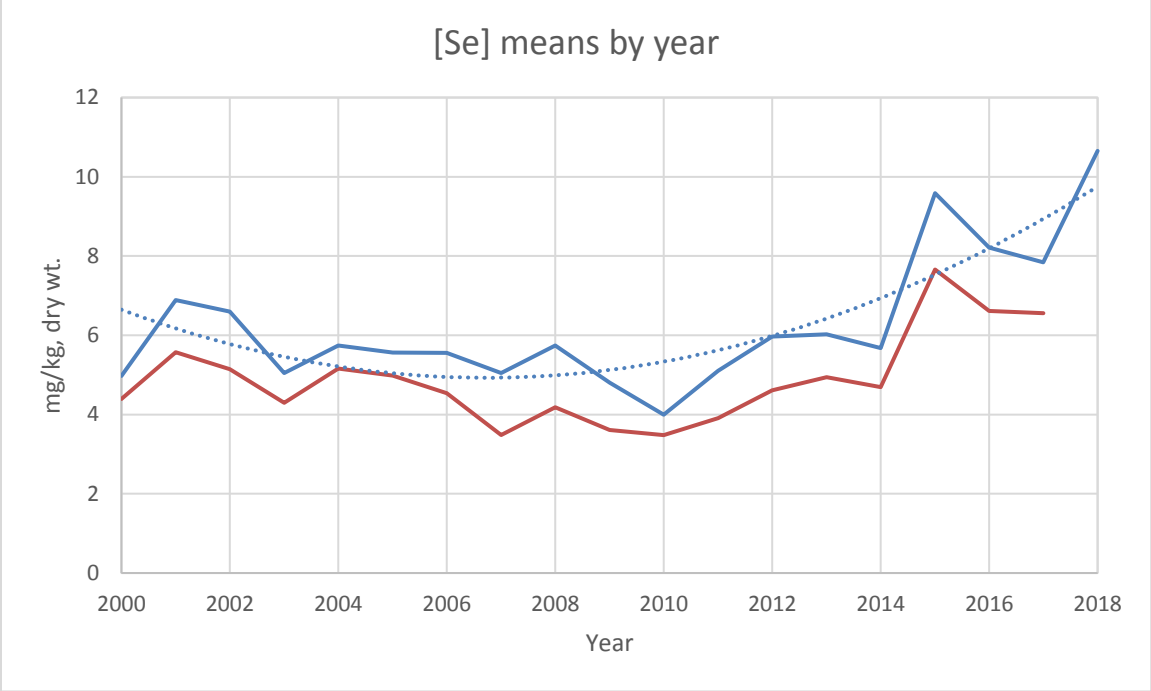

Hg Results
mg/kg, dw
10
9
8
7
6
5
4
3
2
1
0
Mar-00
Dec-02
Sep-05
Jun-08
Feb-11
Nov-13
Aug-16

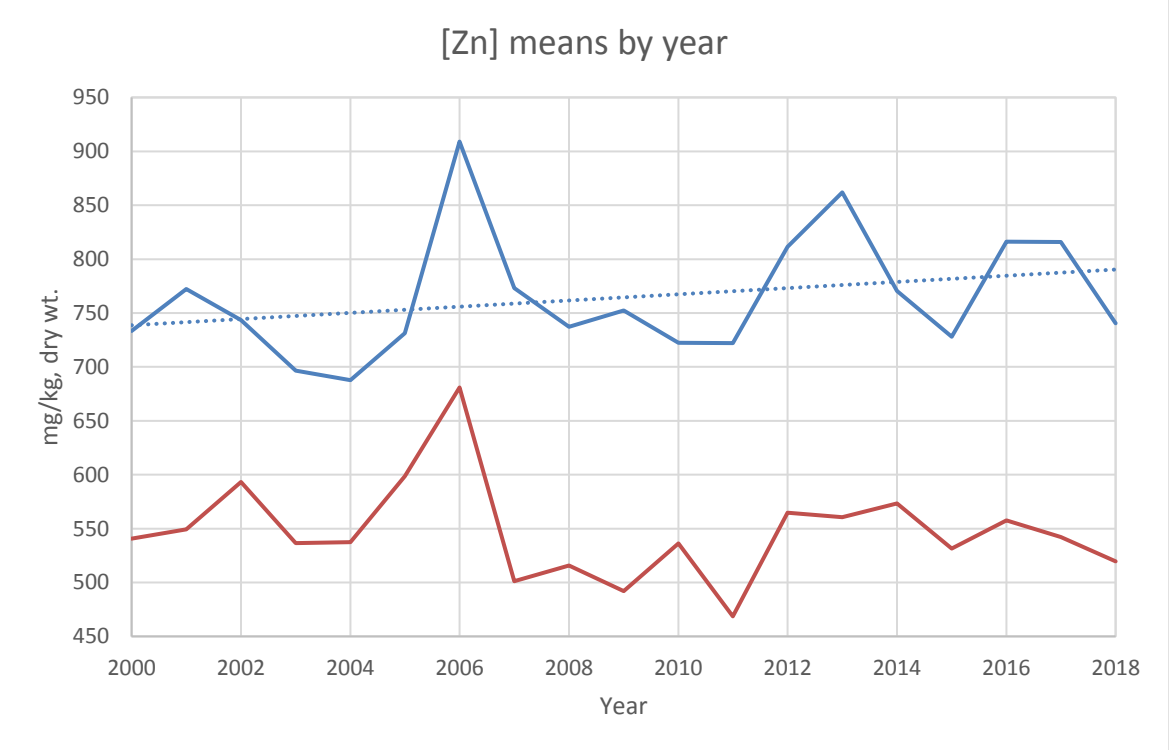

[Pb] means by year
mg/kg, dry wt.
60
50
40
30
20
10
0
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year


Pb Results
mg/kg, dw
200
180
160
140
120
100
80
60
40
20
0
Mar-00
Dec-02
Sep-05
Jun-08
Feb-11
Nov-13
Aug-16


[Mo] means by year
mg/kg, dry wt.
25
20
15
10
5
0
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year


[Ni] means by year
mg/kg, dry wt.
60
50
40
30
20
10
0
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year


[Se] means by year
mg/kg, dry wt.
12
10
8
6
4
2
0
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year


[Zn] means by year
mg/kg, dry wt.
950
900
850
800
750
700
650
600
550
500
450
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year

# APPENDIX 11: Land Application Sites in Vermont

**List complete as of 3/1/18 – Class B biosolids, residual dairy waste, and septage only**

**TYPE codes: S = septage D = Dairy B = Biosolids**

| PERMITTEE | SITE NAME | ACRES | LOCATION | TYPE | CROP | NOTES |
|---|---|---|---|---|---|---|
| Barre Septic | Brown | 7.9 | Brookfield | S | hay | |
| Ben & Jerry's | Neill 10 | 14.8 | Waitsfield | D | feed corn | B&J dairy waste only |
| Ben & Jerry's | Neill 10* | 4.5 | Waitsfield | D | feed corn | B&J dairy waste only |
| Ben & Jerry's | Neill 4 | 31.6 | Waitsfield | D | feed corn | B&J dairy waste only |
| Bradford | Limlaw | 8 | Bradford | B | feed corn | |
| Entergy Nuclear | North | 7.4 | Vernon | S | hay | { septage generated on-site in the |
| Entergy Nuclear | South | 1.9 | Vernon | S | hay | { Central Office Bldg. only. |
| Fairfax | Toof | 3.7 | Fairfax | B | feed corn | |
| Hartford/WRJ | Green Acres 1 | 34 | Hartland | B | feed corn | |
| Hartford/WRJ | Green Acres 2 | 7 | Hartland | B | feed corn | |
| Hartford/WRJ | Green Acres 3 | 28 | Hartland | B | feed corn | |
| Hartford/WRJ | Green Acres 4 | 5.5 | Hartland | B | feed corn | |
| Hartford/WRJ | Green Acres 5 | 17 | Hartland | B | feed corn | |
| Hartford/WRJ | Quechee Lakes | 18 | Hartford | B | feed corn | |
| Jay's Septic | Site 1 | 11 | Fairlee | S | feed corn | |
| Jay's Septic | Site 2 | 11 | Fairlee | S | feed corn | |
| Jay's Septic | Site 4 | 12 | Fairlee | S | feed corn | |
| Jay's Septic | Site 5 | 5.5 | Fairlee | S | feed corn | |
| Jay's Septic | Site 8 | 8 | Fairlee | S | feed corn | currently inactive |
| Londonderry | Lower | 5.5 | Londonderry | S | hay | septage site |
| Londonderry | Upper | 1.7 | Londonderry | S | hay | septage site |
| Michaud Septic | Michaud 3 | 5.6 | Hardwick | S | hay | |
| Michaud Septic | Michaud 4 | 8.5 | Hardwick | S | hay | |
| Michaud Septic | Michaud 5 | 8.3 | Hardwick | S | hay | |
| Essex Jct. | Farr 1 | 18.8 | Richmond | B | feed corn | currently inactive |
| Essex Jct. | Farr 1A | 24.2 | Richmond | B | feed corn | currently inactive |
| Essex Jct. | Whitcomb 10 | 17.2 | Essex | B | feed corn | |
| Essex Jct. | Whitcomb 11 | 15.5 | Essex | B | feed corn | |
| Essex Jct. | Whitcomb 14 | 24 | Essex | B | feed corn | |
| Essex Jct. | Whitcomb 16 | 26 | Essex | B | feed corn | |
| Essex Jct. | Whitcomb 2 | 18.5 | Essex | B | feed corn | |
| Essex Jct. | Whitcomb 3 | 21.6 | Essex | B | feed corn | |
| Essex Jct. | Whitcomb 4 | 23.2 | Essex | B | feed corn | |
| Essex Jct. | Whitcomb 5 | 11 | Essex | B | feed corn | |
| P&P Septic | Garvey 1 | 27.6 | Hinesburg | S | hay | |

# WASTEWATER TREATMENT SLUDGE AND SEPTAGE MANAGEMENT IN VERMONT
## May 2018

| PERMITTEE | SITE NAME | ACRES | LOCATION | TYPE | CROP | NOTES |
|---|---|---|---|---|---|---|
| P&P Septic | Garvey 2 | 21.3 | Hinesburg | S | hay | |
| P&P Septic | Venture A | 35 | Richmond | S | feed corn | |
| P&P Septic | Venture B | 7.3 | Richmond | S | feed corn | |
| P&P Septic | Venture C | 14.5 | Richmond | S | feed corn | |
| Silloway Septic | Silloway | 10 | Randolph | S | feed corn | |
| Silloway Septic | Townsend 2 | 14 | Bethel | S | feed corn | currently inactive |
| Silloway Septic | Townsend 3 | 30 | Bethel | S | feed corn | |
| St. Johnsbury | Denio 1 | 12 | Danville | B | feed corn | |
| St. Johnsbury | Simmer 6 | 11.8 | Barnet | B | feed corn | |
| St. Johnsbury | Simmer 7 | 15 | Waterford | B | feed corn | |
| St. Johnsbury | Simmer 8 | 10 | Waterford | B | feed corn | |
| St. Johnsbury | McReynolds 1 | 15 | Danville | B | feed corn | |
| St. Johnsbury | McReynolds 5 | 30 | Danville | B | feed corn | |
| St. Johnsbury | Olcutt 4 | 22.8 | St. Johnsbury | B | feed corn | |
| Swanton | Robinson 1 | 18.5 | Swanton | B | feed corn | |
| Swanton | Robinson 2 | 5 | Swanton | B | feed corn | |
| Swanton | Robinson 3 | 39.1 | Swanton | B | feed corn | |
| Vergennes | Job Corp | 30.9 | Vergennes | B | feed corn | |
| Waterbury | Treatment Plant | 15.6 | Waterbury | B | feed corn | |
| Windsor | Redick 1 | 14.5 | Windsor | B | feed corn | |
| Windsor | Redick 2 | 21 | Windsor | B | feed corn | |
| Windsor | Redick 3 | 24.5 | Windsor | B | feed corn | |
| Windsor | Redick 4 | 5.5 | Windsor | B | feed corn | |
| Windsor | Redick 5 | 5 | Windsor | B | feed corn | |
| Windsor | Redick 6 | 32 | Windsor | B | feed corn | |
| Woodstock | Bailey | 2 | Woodstock | B | feed corn | |
| Woodstock | Debevois | 16 | Woodstock | B | feed corn | |
| Woodstock | Maxham | 4 | Woodstock | B | feed corn | |
| Woodstock | Treatment Plant 1 | 6 | Woodstock | B | feed corn | |
| Working Dog Septic | Sweet Farm | 30 | Fairfax | S | feed corn | |

Permitted acreage: Biosolids - 677.4 acres Septage - 284.0 acres

# APPENDIX 12: Acronyms

| Acronym | Definition |
|---|---|
| ADI | Acceptable Daily Intake |
| ANR | Vermont Agency of Natural Resources |
| ANSI | American National Standards Institute |
| APLR | Annual Pollutant Loading Rate |
| BOD | Biochemical Oxygen Demand |
| CDC | Centers for Disease Control |
| CEC | Contaminants of Emerging Concern |
| CFR | Code of Federal Regulations |
| CPLR | Cumulative Pollutant Loading Rate |
| CSWD | Chittenden Solid Waste District |
| CWA | Clean Water Act |
| DAFM | Vermont Department of Agriculture, Food & Markets (now VAAFM) |
| DEC | Vermont Department of Environmental Conservation |
| EDC | Endocrine Disrupting Compound |
| EQ | Exceptional Quality (biosolids) |
| FTE | Full Time Equivalents |
| ISCORS | Interagency Steering Committee on Radiation Standards |
| MQL | Method Quantification Limit |
| NEBRA | North East Biosolids and Residuals Association |
| NOAEL | No Observable Adverse Effect Level |
| NPDES | National Pollutant Discharge Elimination System |
| NRC | National Research Council |
| NSF | National Sanitation Foundation (now NSF International) |
| OECA | EPA's Office of Enforcement and Compliance Assistance |
| PAH | Polyaromatic Hydrocarbon |
| PBDE | Polybrominated Diphenyl Ether (flame retardants) |
| PCB | Polychlorinated Biphenyl |
| PCDD/PCDF | Polychlorinated Dibenzodioxin/dibenzofuran (dioxins) |
| PEC | EPA's Pathogen Equivalency Committee |
| PFOA | Perfluorooctanoic acid |
| PFOS | Perfluorooctane sulfonic acid |
| PFRP | Process to Further Reduce Pathogens |
| PPCP | Pharmaceutical and Personal Care Products |
| PSRP | Process to Significantly Reduce Pathogens |
| RfD | Risk Reference Dose |
| TCLP | Toxicity Characteristic Leaching Procedure |
| TEF | Toxic Equivalency Factor |
| TEQ | Toxic Equivalents |
| TMDL | Total Maximum Daily Load |
| TNSSS | Targeted National Sewage Sludge Survey |
| USDA | United States Department of Agriculture |
| USEPA (EPA) | United States Environmental Protection Agency |
| VAAFM | Vermont Agency of Agriculture, Food & Markets |
| VAR | Vector Attraction Reduction |
| VDH | Vermont Department of Health |
| VSWMR | Vermont Solid Waste Management Rules |
| WEP | Water Extractable Phosphorus |
| WERF | Water Environment Research Foundation |
| WWTF | Wastewater Treatment Facility |